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Volume 30 JANUARY, 1946 Number 1

BULLETIN
of the
American Association of Petroleum Geologists

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BULLETIN

of the

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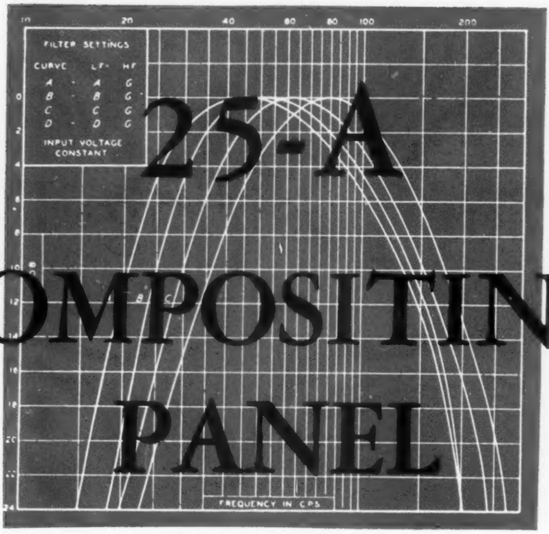

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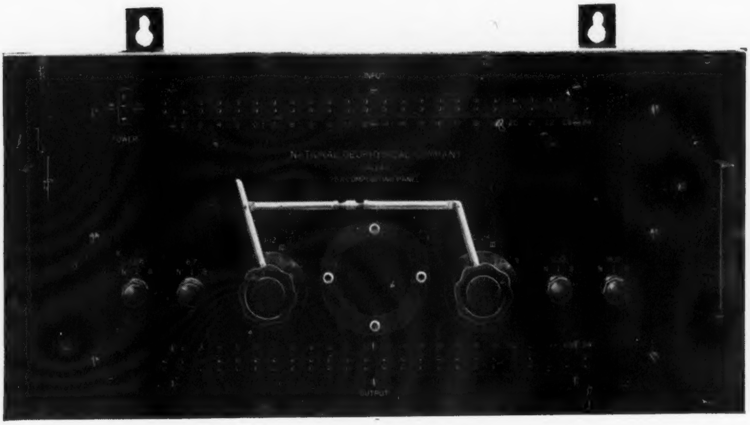

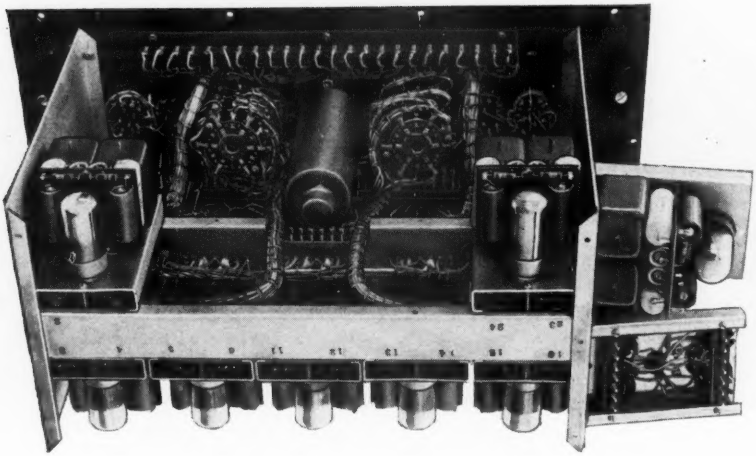

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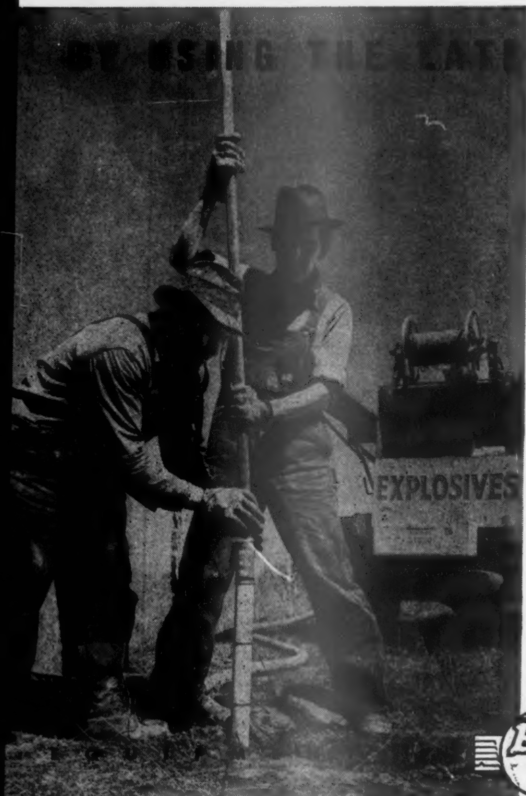

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Volume 30 Number 1

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JANUARY, 1946

GEOLOGY OF OIL BASINS OF EAST INDIAN ARCHIPELAGO[1]

H. M. SCHUPPLI[2]
Calgary, Canada

ABSTRACT

The oil fields of the Tertiary basins of Sumatra, Java, and Borneo have produced more than one billion barrels of oil to the end of 1940. The proved fields still represent a considerable reserve and many undeveloped areas of the Archipelago have excellent possibilities.

The oil produced to date has been derived almost exclusively from sands of Miocene and Pliocene age. Shortly before the Japanese invasion, however, commercial accumulations were discovered in beds of Eocene age. The Boela field, in Ceram, probably produces Triassic oil, accumulated in overlapping sands of Plio-Pleistocene age.

Rather gentle to moderately steep anticlines are the traps for the accumulation of the oil. Stratigraphic traps are undoubtedly present but they are not yet explored.

From the point of view of Tertiary geotectonics the East Indian Archipelago is an area of great complexity and of special interest. Two major geosynclinal belts, folded into orogenes by subsequent mountain-building phases, meet in this area. These are the circum-Asiatic geosyncline, a part of the world-wide Tethys geosyncline, and the Australo-Pacific geosyncline. The Tertiary basins of Borneo are outside these two belts. The latter basins lie within, although near the edge of, the Asiatic continent, constituting intra-continental geosynclines.

An accompanying geotectonic sketch map shows the location of the oil-producing areas of the East Indian Archipelago.

These notes attempt to analyze the regional tectonic position of the Tertiary basins of the East Indian Archipelago. A very interesting paper on the stratigraphy of this region was published rather recently in this *Bulletin* (E. W. Beltz, 1). For this reason it seems advisable to emphasize here the tectonic problems. The stratigraphy is summarized and some data on developments and production in the different oil basins added. Because of the restricted amount of material at hand, these latter discussions particularly are incomplete.

[1] Manuscript received, August 6, 1945.

[2] Shell Oil Company of Canada, Limited. Formerly Bataafsche Petroleum Maatschappij, The Hague, Holland.

The writer is indebted to the Management of the Bataafache Petroleum Maatschappij in London for providing facilities and for permission to publish this paper. He wishes to thank Lieutenant Colonel L. A. de Laive in charge of the oil department of the Nederlands Representatives to the Combined Chiefs of Staff, Washington, D. C., for making available data on East Indian oil fields on file at his office.

Valuable help also was received from H. Ten Broeke, Shell Oil Company, Incorporated, Centralia, Illinois, formerly Bataafsche Petroleum Maatschappij, The Hague, Holland. The writer furthermore gratefully acknowledges the help of L. M. Clark and H. D. Curry of the Shell Oil Company of Canada, Limited, in editing this article.

I. Stratigraphy

PRE-TERTIARY

Permo-Carboniferous.—The oldest sedimentary series of definitely determinable age belongs to the Permo-Carboniferous. This series is described from the mountain ranges forming the backbone of Sumatra, from the Timor-Ceram row of islands, and from Borneo, Celebes, New Guinea, and other islands. Special mention should be made of the highly fossiliferous Permian section of Timor. Excellent collections of exceptionally well preserved fossils have been made, particularly in tuffaceous marls, of this section, including more than 70 genera and 239 species of crinoids. According to H. A. Brouwer (2), 42 of these 70 genera have been found only in Timor. On the other hand, this fauna shows affinities to Permian faunas in the Alps and the Himalayas, which indicates that the Tethys geosyncline was present to some extent as early as Permian time, connecting the Mediterranean area with the East Indian Archipelago.

Glacial deposits known to be widely distributed in India and Australia have not been found among the upper Paleozoic beds of the Archipelago. This may be explained by the oceanic character of this area at these times.

Triassic and Jurassic.—Triassic and Jurassic rocks are known from many islands, especially in the eastern parts of the Archipelago. The Triassic is reported to be present in two distinctly different facies. The cephalopod limestones of Timor, many of them red and manganese-bearing, are associated with tuffs and radiolarian cherts and are considered to represent deep-sea deposits. From Timor, Ceram, Boeton, and other islands of the Moluccas, a shallow, marine sandstone-shale section, in places "Flysch-like" in character, is described. This section is more or less oil-bearing in some areas.

Jurassic sediments, like the Triassic, are known to be partly of deep-sea facies, partly shallow marine.

Cretaceous.—Beds of definitely Lower Cretaceous age have been reported only from a few areas, but the Upper Cretaceous is extensively developed. The Tethys character of these beds and of the Mesozoic in general is in places very striking. The association of radiolarites and basic eruptives (ophiolites) is typical in this respect and the Upper Cretaceous "couches rouges" and "Seewer beds" of the Alps show remarkable similarities in lithology and fauna to beds of widespread occurrence in the Moluccas.

Metamorphic rocks.—Crystalline schists and other metamorphic rocks are reported from the mountain ranges of many islands. They were first considered to be as ancient as pre-Cambrian. More and more, however, it was demonstrated that many of them are much younger, belonging to the Paleozoic and Mesozoic. Rather recently, even crystalline schists of Eocene age, containing *Nummulites*, were discovered in western Borneo. Intense folding, igneous intrusions, and deep burial by superimposed Tertiary sections of great thickness have metamorphosed these comparatively young beds.

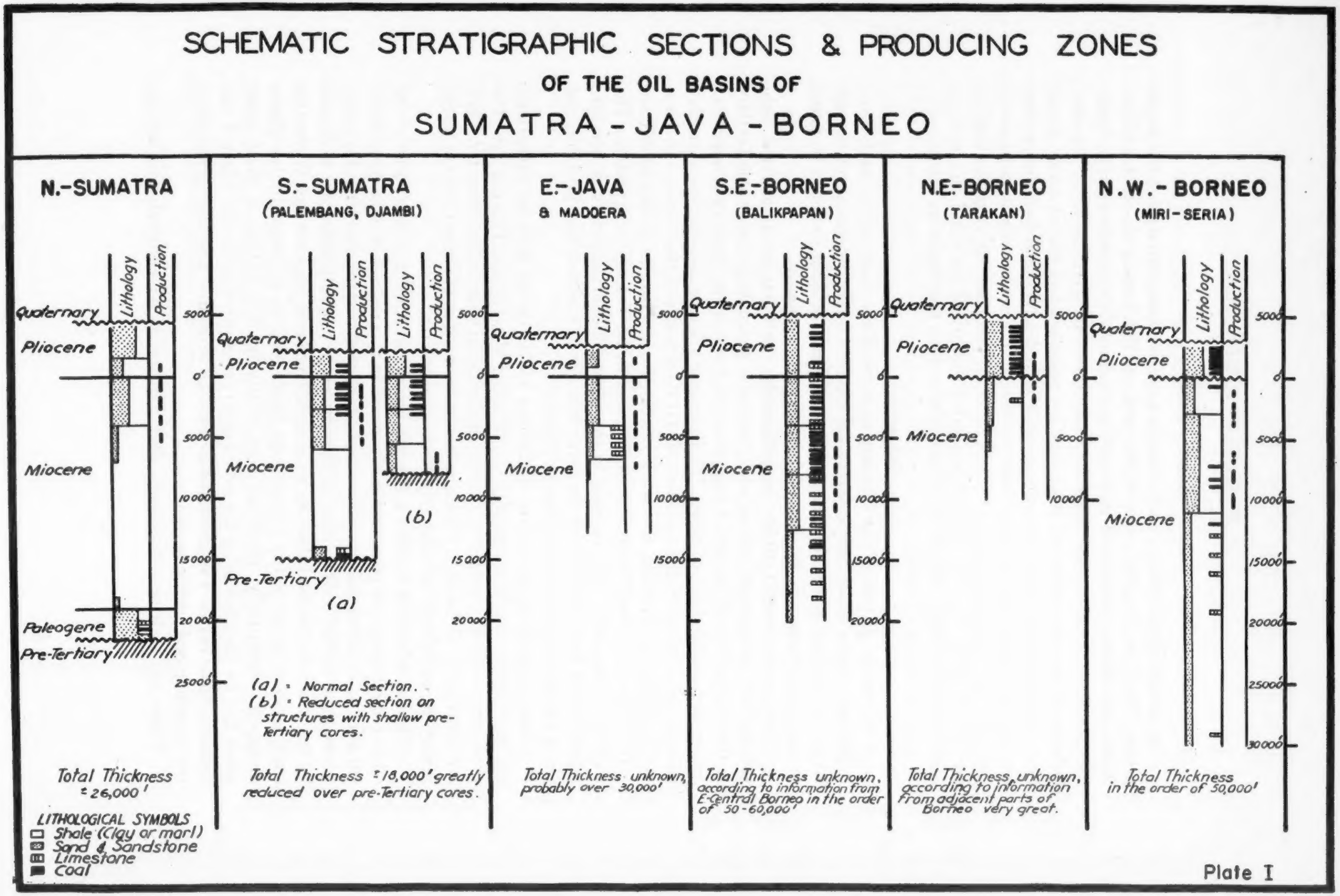
SCHEMATIC STRATIGRAPHIC SECTIONS & PRODUCING ZONES
OF THE OIL BASINS OF
SUMATRA - JAVA - BORNEO
N.-SUMATRA
S.-SUMATRA (PALEMBANG, DJAMBI)
E.-JAVA & MADOERA
S.E.-BORNEO (BALIKPAPAN)
N.E.-BORNEO (TARAKAN)
N.W.-BORNEO (MIRI-SERIA)
Lithology
Production
Quaternary
Pliocene
Miocene
Paleogene
Pre-Tertiary
(a)
(b)
(a) : Normal Section.
(b) : Reduced section on structures with shallow pre-Tertiary cores.
Total Thickness ± 26,000'
Total Thickness ± 18,000' greatly reduced over pre-Tertiary cores.
Total Thickness unknown, probably over 30,000'
Total Thickness unknown, according to information from E-Central Borneo in the order of 50-60,000'
Total Thickness unknown, according to information from adjacent parts of Borneo very great.
Total Thickness in the order of 50,000'
LITHOLOGICAL SYMBOLS
Shale (Clay or marl)
Sand & Sandstone
Limestone
Coal
Plate I

FIG. I

IGNEOUS ROCKS

Igneous rocks of intrusive and extrusive type are known throughout the Archipelago. Many are of great economic importance. The famous tin-ore deposits of Banka and Biliton are related to granitic intrusions of Cretaceous age (5). Granitic intrusions are also responsible for many economic gold and silver deposits. Other such ores are associated with Tertiary andesites and related rocks. Many basic igneous rocks are of importance with regard to residual iron ores, nickel, manganese, chromium, *et cetera*. Last but not least, the economic importance of the tuffs and erosional products of the Quaternary and Recent volcanics may be mentioned. Java, the most densely populated country of the world, can feed and sustain its population only because of the incredible fertility of its volcanic soil.

TERTIARY

A schematic picture of the Tertiary sections of the main oil basins is given in Figure 1. Some stratigraphic details are included in the discussions of the different oil-producing areas and many interesting stratigraphic data can be found in the publication of E. W. Beltz (1) mentioned previously.

A few points brought out by the stratigraphic chart may be summarized. Subsidence was particularly strong and consistent throughout the whole Tertiary in the geosynclines of Borneo. A composite thickness of the Tertiary of more than 50,000 feet can be observed there. The Paleogene (Eocene and Oligocene) reaches thicknesses of more than 15,000 feet. Total thicknesses of the Tertiary in Java, and especially in Sumatra, are much smaller, mainly because strong subsidence started later in these basins. In south Sumatra no Paleogene is present. The Paleogene sections locally exposed in the central mountain ranges of northern Sumatra and Java are thin and the lower Miocene of Sumatra and Java does not reach the great thicknesses found in Borneo.

Commercial oil accumulations in the East Indian basins, with two exceptions, are restricted to sands and sandstones of upper Miocene and Pliocene age. The producing sequences are neritic, littoral, and paludal (paralic) in character. They are underlain in all basins by thick, rather uniform series of shales (clays or marls, mainly foraminiferal) of relatively bathyal character.

Without intending to offer a definite opinion about the source rocks of the oil in these basins, one observation of interest in this respect may be mentioned. Oil is found in neritic and near-shore deposits of most varying character. However, where these neritic beds contain oil in commercial quantities they are underlain by the relatively bathyal shale series of middle or lower Miocene age. Where this shale series is developed in a near-shore facies too, the oil seems to dwindle or disappear. Admittedly, there has been relatively little drilling in these latter areas, but for the time being the most logical assumption about the origin of the oil seems to be that it was generated in the shale series and migrated upward into the superimposed neritic section.

Where the statement was made that commercial oil accumulations are re-

stricted to the upper Miocene and the Pliocene, two exceptions were mentioned. One exception is in south Sumatra where, on top of pre-Tertiary highs in some anticlinal cores, the lower Miocene shale section is greatly reduced in thickness and contains sand intercalations. Some of these sands are highly productive. This oil no doubt originated in the surrounding synclines where the normal shaly development of this series can be expected. The second exception refers to the Barito basin in southeastern Borneo, where shortly before the war commercial oil accumulations were discovered in beds of Eocene age.

II. Regional Geological Position of Tertiary Basins

From the point of view of Tertiary geotectonics, the East Indian Archipelago is an area of great complexity and of special interest. It also is an area of very controversial interpretation. It is believed, however, based on published information and on the extensive factual material collected by geologists of the Bataafsche Petroleum Maatschappij, that a relatively satisfactory analysis is possible.

Three major tectonic elements of continental character (continental blocks[3]) meet in this area. These are the old Gondwana continent (India-Australia), the Asiatic continent (Siam-Malacca-Indo China), and the rigid block or blocks of the Pacific Ocean (Fig. 2).

FOLD ARCS OR OROGENES

Between the major tectonic blocks, and in some places within them, in a rather complicated array, lie the young fold-arcs or orogenes[4] of the Archipelago. They can be grouped into three units.

1. A fold-arc which follows the outer edge of the Asiatic continental block, and therefore can be called the circum-Asiatic Tertiary orogene. It has arisen from a Tertiary geosynclinal zone representing part of the "Tethys," which as a mobile belt can be followed from the Alps over the Caucasus and the Himalayas and on through Japan. From here it swings northeastward and possibly connects with the Aleutian Range and circum-Pacific orogene of the western Americas.
2. The young fold-arcs derived from geosynclinal basins lying between the Australian continent and the rigid blocks of the Pacific Ocean (*Australo-Pacific Tertiary orogene*).
3. The Tertiary fold-arcs lying within the Asiatic continent derived from intra-continental geosynclinal basins (*Intra-Asiatic Tertiary orogenes*).

CIRCUM-ASIATIC TERTIARY OROGENE

The Tertiary orogene of the southwestern part of the Archipelago (Sumatra and Java) and its northern extension over the Nicobar-Andaman Islands into

[3] By "*continental blocks*" is meant areas which during Tertiary time in general were not geosynclinal and therefore behaved as rigid masses.

[4] "*Geosynclines*" in these discussions mean areas of strong subsidence and sedimentation during Tertiary time, which by one or more mountain-building phases were folded into "*orogenes*."

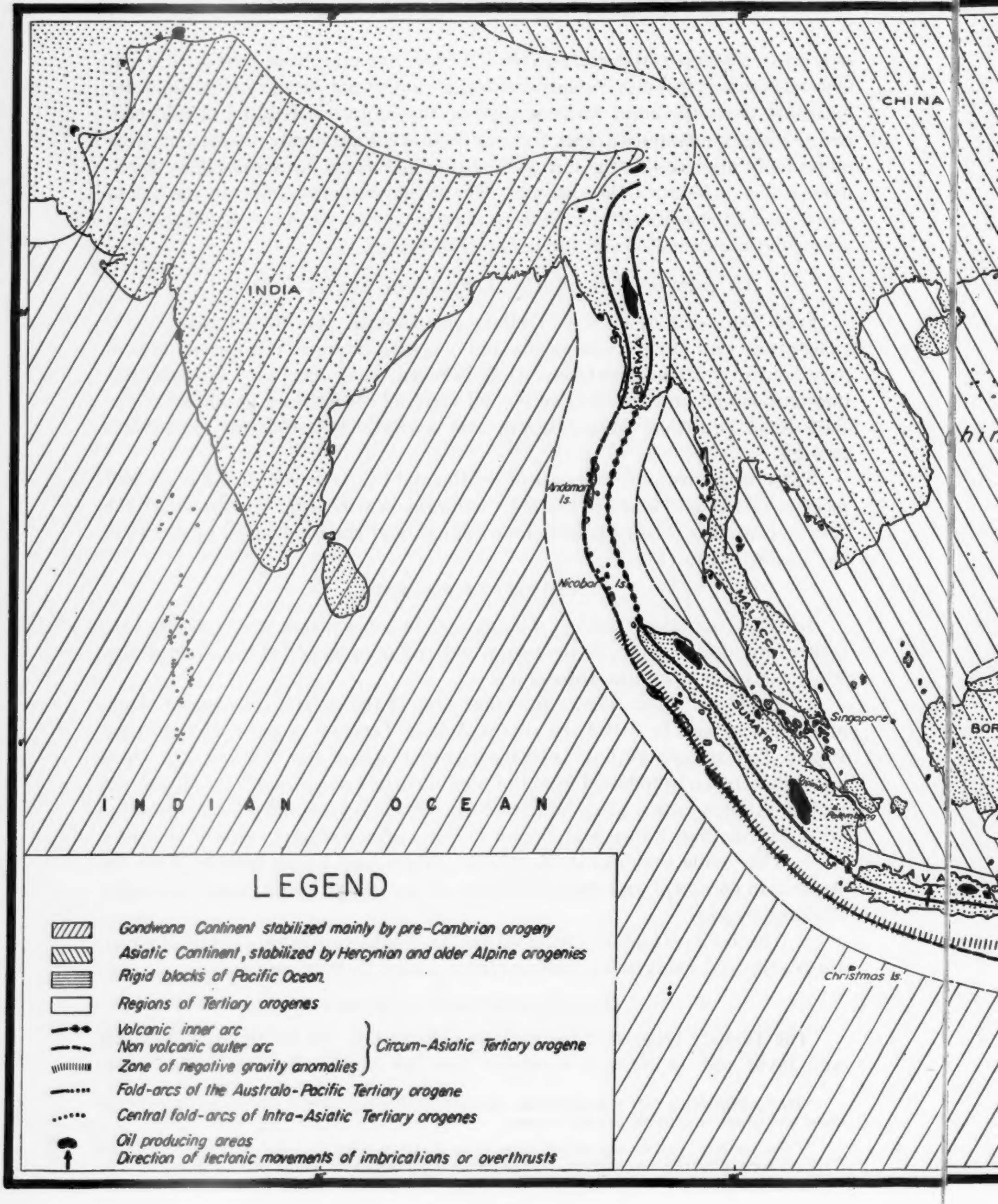
CHINA
INDIA
BURMA
Andaman Is.
Nicobar Is.
MALACCA
Singapore
SUMATRA
Palembang
JAVA
BOR
Christmas Is.
INDIAN OCEAN
LEGEND
Gondwana Continent stabilized mainly by pre-Cambrian orogeny
Asiatic Continent, stabilized by Hercynian and older Alpine orogenies
Rigid blocks of Pacific Ocean.
Regions of Tertiary orogenes
Volcanic inner arc
Non volcanic outer arc
Zone of negative gravity anomalies
Circum-Asiatic Tertiary orogene
Fold-arcs of the Australo-Pacific Tertiary orogene
Central fold-arcs of Intra-Asiatic Tertiary orogenes
Oil producing areas
Direction of tectonic movements of imbrications or overthrusts

FIG. 2 (West)

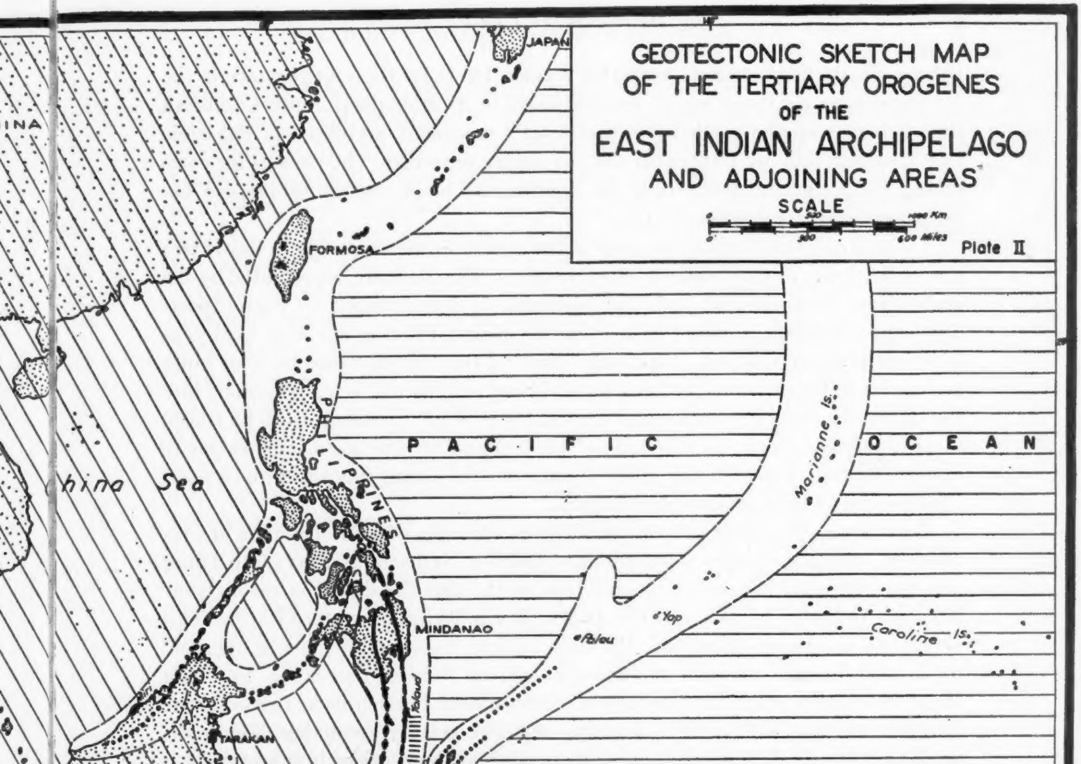
GEOTECTONIC SKETCH MAP
OF THE TERTIARY OROGENES
OF THE
EAST INDIAN ARCHIPELAGO
AND ADJOINING AREAS
SCALE
Plate II
JAPAN
FORMOSA
P A C I F I C
O C E A N
Marianne Is.
MINDANAO
Palau
Yap
Caroline Is.
TARAKAN
BORNEO
HALMAHEIRA
Strait of Makassar
CERAM
BOETON
MADOERA
TIMOR
TENIMBER
NEW GUINEA
AUSTRALIA

FIG. 2 (East)

Burma clearly lies between two stable masses. Of these the southwestern is the old Gondwana continent which was stabilized in its main parts in pre-Cambrian time, whereas on the northeast is the Asiatic continent, stabilized in Paleozoic and Mesozoic time by Hercynian and old Alpine orogenies. The reasons for combining India and Australia into one continental block, partly submerged beneath sea-level, are discussed later.

Inner arc.—The Tertiary orogene in the area of Sumatra and Java shows two geanticlinal arcs of very distinct characteristics. The inner arc, represented by the geanticlinal backbones of Java and Sumatra, is characterized by young (post-Tertiary) volcanism, a main phase of folding of post-Pliocene age, and locally, as in the central parts of Java, northward-directed tectonic movements. This inner arc can be followed from Java eastward through a chain of volcanic islands into the Banda Sea between Ceram and Timor. From North Sumatra it can be traced through some volcanic islands (east of the Andamans) and submarine ridges to eastern Burma, where in the lower Chindwin area young volcanoes and a post-Pliocene major folding phase occur again.

Outer arc.—The outer arc can be followed through a chain of islands or pronounced submarine ridges southwest and south of Sumatra and Java into Timor and the Tenimber Islands at the east; and in the opposite direction through the Nicobar-Andaman Islands, into the Arakan Jomas Range of western Burma. This arc shows no young volcanism. Its main folding phase is Miocene in age, and southward-directed tectonic movements occur on some of its islands. In Timor these movements reach the intensity of thrust sheets. Furthermore, this outer arc roughly coincides with a zone of strong negative gravity anomalies. This zone, established by F. A. Vening Meinesz by pendulum observations in submarines, is of particular interest and is further discussed later.

The circum-Asiatic orogene thus shows the tendency to a bilaterally symmetric structure, tectonic movements of the inner arc being directed locally toward the adjacent Asiatic continent; while in the outer arc these movements are directed locally toward the adjacent Gondwana continent. In this respect a certain similarity with the structure of the orogene of the Alps is evident.

It has been demonstrated that this orogene can be followed without difficulty from Burma to the eastern Moluccas. It furthermore is plainly recognizable from the Philippines northward to Formosa and Japan and therefore must be also between the eastern Moluccas and the Philippines. This last connection however is difficult and much disputed. Observations made in Celebes offer the key to it. The western part of this island clearly shows the characteristics of the inner arc, that is, post-Pliocene folding, westward-directed tectonic movements (thus toward the Asiatic continent) and at least some areas of young volcanism. The latter can be followed over the northwest arm of Celebes and a row of small volcanic islands into central Mindanao.

In contrast to this, eastern Celebes shows typically the properties of the outer arc, that is, Miocene folding which in the north arm of eastern Celebes caused

southeastward-directed overthrusts, and no young volcanoes. Here the bilaterally symmetrical structure of this Tertiary orogene is very plainly developed. The outer arc connects notheastward through submarine ridges and the Talaud Islands with eastern Mindanao; and southeastward through the islands of Boeton, Boeroe, and Ceram, with Tenimber and Timor. Last but not least, the zone of strong negative gravity anomalies, typical of the outer arc, clearly connects Ceram with Tenimber and Timor, and is well developed between Halmaheira and Celebes and just east of Talaud. The gravity observations in the seas between Ceram and Celebes are too widely spaced for the complications of this area, and alternative interpretations are possible. In his first provisional publication, dated 1930, Vening Meinesz connected the negative zone of Ceram northwestward with the negative zone between Halmaheira and Celebes (W. H. Bucher, 3, Fig. 61). When his attention was drawn to the likelihood of a connection of Ceram with Boeton and Celebes he remarked that his final computation of the gravity data also favored this correlation. In his 1934 publication (4), which also includes discussion of the geology and the submarine topography of the Archipelago by T. H. F. Umbgrove and P. H. H. Kuenen, he changed his interpretation accordingly. This later interpretation is indicated in Figure 2 of the present paper.

After establishment of the course of the circum-Asiatic orogene as a key-line throughout the Archipelago, the remaining Tertiary orogenes obviously have to be grouped into two additional units, one on the west and one on the east of it.

AUSTRALO-PACIFIC TERTIARY OROGENE

This orogene embraces the Tertiary fold arcs of New Guinea and Halmaheira, which evidently lie between two blocks of continental character. These are the Australian (Gondwana) continent in the south and the rigid masses of the Pacific in the north. Observations made by J. Zwierzycki, a geologist of the Netherlands East Indian Geological Survey, strongly indicate that in late Tertiary time dry land which was a source area for Tertiary sediments must have existed just north of the north coast of middle New Guinea.

The similarity in geological position with the circum-Asiatic orogene is reflected in a similar tectonic structure. Two geanticlinal fold-arcs are recognized in middle New Guinea, one close to and paralleling the north coast, the other forming the central mountain ranges of the island. The northern arc shows northward-directed tectonic movements, whereas indications of southward-directed thrust sheets are reported from the central ranges. Thus, this orogene also has a structural bilateral symmetry similar to the circum-Asiatic orogene.

The extension of the two New Guinea arcs into Halmaheira is tentative. Very little is known of the geology of this island, which shows a rather striking similarity in its outlines with Celebes. It is possible that this similarity is due to similar geotectonic positions of the two islands, that is, both being situated in a pronounced bend of a double fold-arc. This indicates that from Halmaheira the Australo-Pacific orogene extends northeastward into the submarine ridges and island rows of the Pacific (Palau-Yap and Mariana Islands).

INTRA-CONTINENTAL TERTIARY OROGENES OF ASIATIC CONTINENT

From observations of geological, geophysical, and morphological nature, it has to be concluded that many areas of the Archipelago, now covered by sea, must have been dry land in Tertiary time. For instance, as is discussed later, there must have been dry land close to the present northern shores of Java, from which was derived the terrigenous material of the young Tertiary sediments of this island. This landmass very probably extended northeast over the area of the Strait of Makassar (between Celebes and Borneo). The results of gravity surveys in the coastal areas of southeastern Borneo and western Celebes indicate a pronounced seaward rising of the pre-Tertiary basement toward this strait. Moreover, the geology of southeastern Borneo and western Celebes tends to prove that these areas were part of two different geosynclines in Tertiary time. The Celebes Sea, bounded by Celebes, Borneo and the Philippines, according to its morphology and gravity observations by Vening Meinesz, can be understood best as a continental area that subsided rather recently along zones of faulting (4).

From this, and from the fact that the circum-Asiatic geosyncline was situated east of Borneo, it must be concluded that the geosynclinal areas of Borneo are situated within, although close to the edge of, the Asiatic continent. This conclusion is supported by the observation that these Borneo geosynclines differ markedly from the circum-continental geosynclines or orogenes previously discussed.

As already mentioned, the Tertiary basins of Borneo have much thicker sections than those of Sumatra or Java and particularly is this true of the Paleogene sections. They show no signs of the intensive late volcanic activity which characterizes the circum-Asiatic inner arc. They furthermore do not show the bilaterally symmetric structure of the circum-continental orogenes with opposing outward-directed tectonic movements of the inner and outer arcs. The structure of the southeast Borneo basin is characterized by one centrally situated geanticline, the Meratoes Mountains. A similar central geanticline is probably present in the northwest Borneo basin.

The geology of the northern parts of central Borneo and of the rows of islands between Borneo and the Philippines is not yet clearly understood. The interpretation of these areas therefore is merely tentative. In the Philippines there seems to be a convergence of the northern continuation of the intra-continental orogenes with the arcs of the circum-Asiatic orogene. This possibly accounts for the complicated tectonic structure of this island group.

VENING MEINESZ' GRAVITY SURVEY

The importance of the results of this survey as a help in understanding the geotectonics of the Archipelago and of orogenetic processes in general can hardly be overestimated. A few of his conclusions may be summarized. His zone or belt of negative gravity anomalies, bordered on both sides by broad fields of positive anomalies, has a width on the order of 100 miles. It differs from the neighboring

positive areas by about 150 to 200 milligals and locally more than 350 milligals. Because it nearly coincides with islands or submarine ridges, and because of the magnitude of the anomalies, it can not be explained as an uncompensated topographic mass defect. It furthermore can not be related with irregularities in the substratum, as the gradients of the negative anomalies are too steep. A depth of these anomalies of about 40 kilometers (about 25 miles) seems to be the maximum, which means that they must be related to mass disturbances within the crust or at its lower boundary. Vening Meinesz thinks that it is caused by a downward fold ing of the acid crust into heavier masses of the substratum. This downward bulge is associated with an upward folding of the near-surface parts of the crust, causing the geanticlinal islands and submarine ridges coinciding with or paralleling the negative zone. This upward folding however is considered as rather insignificant in comparison with the downward bulge. He furthermore concludes that the belt of negative anomalies is a border effect of the Asiatic continent, and that the compressional forces causing them are still active at the present time. This is confirmed by geological observations. The majority of the epicenters of earthquakes are located within and around the negative belt. Furthermore, the upheaval of young coral reefs in the Timor-Tenimber Island group, locally amounting to more than 3,000 feet, according to Brouwer (2), must have been caused by folding and not by purely vertical epirogenic rise. Brouwer therefore concludes that this island arc which coincides with the belt of negative anomalies is a fold-arc in *status nascendi.* Assuming a thickness of 25 kilometers for the acid crust, Vening Meinesz calculates that the horizontal shortening over the negative belt must be on the order of 50 kilometers. By comparing the intensities of the negative anomalies and the character of the gravity profiles through the negative belt over the whole Archipelago, it is evident that the compressional forces did not act with the same intensity in all directions. He concludes that the Asiatic continent exerted pressure south-southeast, and the rigid blocks of the Pacific weaker pressure west-southwest, while the Gondwana continent was passive. These conditions, together with irregularities in the outlines of the continental masses of Asia and Australia, may account for the complicated course of the circum-Asiatic orogene between New Guinea and Celebes.

Vening Meinesz also draws attention to the remarkable fact that the resistance offered by the Gondwana continent evidently is the same, whether this continental block is represented by the submerged masses of the Indian Ocean or by the island masses of Australia.[5] His conclusion is very clearly supported by the

[5] The Indian Ocean was deep sea probably throughout Tertiary time. Christmas Island, situated in the Indian Ocean about 300 miles south of western Java, is, according to publications by W. Campbell Smith and W. L. F. Nuttall (*Jour. Geol. Soc. London*, 1926) the top of a submarine volcano which rises up more than 13,000 feet from the ocean floor. Paleogene and Miocene limestones, apparently unfolded, overlie alkali-trachytes, alkali-basalts, and other volcanic rocks of the so-called "Atlantic differentiation type." Rocks of this differentiation type, typical of blocks of continental character, are also described from the Caroline Islands of the Pacific block. In contrast with this, the young volcanoes of the inner arc of the circum-Asiatic orogene are characterized by rocks of the "Pacific differentiation type."

continuity of the major tectonic elements of the Tertiary orogene from Burma to the Moluccas. These observations no doubt form a strong argument against the theories of continental drift which assume fundamental differences between the floor of the Indian Ocean and the landmasses of India and Australia.

POSITION OF PRODUCING FIELDS WITHIN TERTIARY BASINS

Figure 2 shows at a glance that no oil-producing areas occur in geanticlinal parts of these basins. To some extent this is because individual structures of these parts are too highly folded, many even having pre-Tertiary cores. Furthermore, these structures are too steep and complicated.

It can be observed throughout the Archipelago that steep anticlines, though a number of such structures were tested, do not contain commercial oil accumulations. In this respect the East Indies area show a fundamental difference from areas like California, western Canada, Trinidad, and Rumania, where prolific oil fields are associated with very steep and highly complicated structures. This striking fact can hardly be understood without assuming vertical migration of oil. Intensive folding no doubt causes shattering of the anticlinal cores by microfaulting, and simultaneous upward migration of oil along the conduits thus created becomes possible. By assuming similar conditions as to stratigraphy, lithology, and regional tectonics, the intensity of folding of a structure must be about proportionate to the intensity of shattering, and also to the amount of vertical migration. This may explain the occurrence of a gentle, highly productive structure close by a non-commercial structure, similar in other respects, but considerably steeper and more complicated. Both structures must have accumulated oil from the surrounding synclinal areas, but in the steep one part of the oil evidently has migrated so high that it is removed now by erosion.

Furthermore, the distribution of the oil fields in South Sumatra and East Java indicates that only structures situated a certain distance from the edges of the basin contain commercial oil accumulations. This can not be due to tectonic reasons, as favorable structures occur in these areas, but must be caused by the facies changes, discussed in the first part of this paper.

III. Developments and Oil Production

The first successful oil wells were drilled in the East Indies by enterprising pioneers in 1885 on the Telagasaid concession in North Sumatra, followed by a shallow discovery in 1888 in East Java in the neighborhood of Soerabaja. The real birth of the East Indian oil industry, however, dates back to 1890 when the Koninklijke Maatschappij tot Ontginning van Petroleumterreinen in Nederlandsch Indie (Royal Company for the Exploitation of Oil Fields in the Netherlands Indies), took over the Telagasaid concession. A few years later oil was discovered in South Sumatra (Palembang) by some small oil companies. These also were absorbed by the rapidly growing "Koninklijke."

A very important step in the development of the "Koninklijke" was the amal-

gamation with the Shell Transport and Trading Company in 1907, which together formed the Royal Dutch-Shell Group. At this time the Bataafsche Petroleum Maatschappij (BPM) was founded as the operating company for the Royal Dutch-Shell in the Netherlands East Indies. The "Bataafsche" took over the exploitation of the oil fields of the "Koninklijke" in Sumatra as well as those of the "Shell" in Eastern Borneo. Later the fields of the "Dordtsche," an independent company, operating in Java, were also taken over by the "Bataafsche," which thus was operating in all the major oil basins of the Archipelago.

For the development of the prolific oil fields of Djambi (South Sumatra) the Netherlands Indies Government became a partner of the BPM in a 50–50 combination (Nederlandsch Indische Aardolie Maatschappij, or NIAM). This company also holds some small concessions in North Sumatra and East Borneo.

In 1912, American interests started oil operations in the Archipelago. The Nederlandsche Koloniale Petroleum Maatschappij (Nederlands Colonial Oil Company), customarily called NKPM, a subsidiary of the Standard-Vacuum Oil Company, which in turn is owned in equal shares by the Standard Oil Company of New Jersey and the Socony-Vacuum Corporation, was founded and started prospecting for oil. Production was first obtained by this company in East Java and later rich oil accumulations were discovered in the Talangakar-Pendopo area of South Sumatra.

In 1931 the Nederlandsche Pacific Petroleum Maatschappij entered the picture. This company, a subsidiary of the Standard Oil Company of California and the Texas Oil Company (Cal-Tex) was carrying out extensive exploration work in the coastal plains of middle Sumatra. Oil in commercial quantities was discovered on two structures in this area, but prewar developments did not reach the stage of commercial production.

The latest development was the creation of the Nederlandsche Nieuw Guinea Petroleum Maatschappij in 1934. The "Royal Dutch-Shell" and the "Standard Vacuum" each have an interest of 40 per cent in this company and the "Cal-Tex" 20 per cent. Extensive exploratory work was carried out in an exploration concession covering 25,000,000 acres in the Netherland part of New Guinea. At the time of the Japanese occupation, commercial accumulation of oil had been proved on some structures in the Vogelkop area, demonstrating that this island may offer oil possibilities of considerable magnitude.

In 1940, from a total production of 66,747,318 barrels (Table I) the Bataafsche Petroleum Maatschappij and its affiliated companies operating in British Borneo and Ceram, together with the NIAM, produced 50,886,538 barrels (76 per cent) and the Nederlandsch Koloniale Petroleum Maatschappij 15,860,180 barrels (24 per cent). Practically all (15,790,214 barrels) of this latter amount was derived from South Sumatra, particularly the Talangakar-Pendopo area.

GENERAL REMARKS

In general, it can be said that in the producing areas of the East Indian Archipelago, as in so many other petroliferous areas, most of the favorable sur-

face structures had been tested at the time of the invasion and were undergoing exploitation at least as far as the relatively shallow Miocene and Pliocene oil zones were concerned. The testing of unexposed structures, located by geophysical methods, had not been attended by much success but such testing was still in progress before the invasion, as was further search for such structures.

It is a striking fact that practically all the oil produced is from relatively shallow depths. Many of the producing structures are explored by deep tests, but in most cases with rather disappointing results. There are two reasons for this. The lower Miocene as a rule is represented by a thick section of decidedly shaly

TABLE I

TOTAL CRUDE OIL AND CASING-HEAD GASOLINE PRODUCTION OF EAST INDIAN ARCHIPELAGO TO END OF 1940 AND DURING 1940

	Year Production Began	*Total Production to End 1940 in Barrels*		*Production during 1940 in Barrels*	
SUMATRA					
North	1893	142,779,224		7,566,707	
South (Djambi)	1923	54,601,783		9,610,560	
South (Palembang)	1898	281,668,685		23,335,596	
Total Sumatra		479,049,692	44.4%	40,512,863	60.7%
JAVA	1886	108,002,410	10.0%	6,090,203	9.1%
BORNEO					
NE. (Tarakan)	1906	143,725,407		5,397,691	
SE. (Balikpapan)	1898	238,637,178		6,926,649	
West (British Borneo)	1913	101,168,000		7,154,000	
Total Borneo		483,530,585	44.9%	19,478,340	29.2%
CERAM	1913	7,474,371	0.7%	665,912	1.0%
TOTAL EAST INDIES		1,078,057,058	100.0%	66,747,318	100.0%

character. Many students of the area think that these shales are the "mother formation" for the oil in overlying beds. These lower Miocene shales in many places have a distinct petroliferous character, but they are also characterized by the absence or scarcity of reservoir rocks. So far, only in the South Sumatra basin is substantial production developed from beds of this age (Telissa formation). This is, as already mentioned, because this basin, in distinction from the others, was not formed until lower Miocene time. The Telissa formation therefore transgresses an old land surface of rather pronounced relief and contains more sand intercalations than the lower Miocene ordinarily contains. A second reason for disappointment is the fact that the structural complications of the producing anticlines seem to increase considerably with depth, making deep drilling a rather risky venture. There can be no doubt however, that the future will see deep discoveries in many areas, bringing to new life many fields now approaching depletion.

Little exploration effort has been directed so far to the discovery of accumula-

tions in stratigraphic traps. Such traps may offer vast possibilities for many areas.

The exploration of undeveloped areas such as Middle Sumatra, West Java, Barito Basin, and New Guinea, to mention some of the larger and more interesting, was in progress at the time of the occupation.

NORTH SUMATRA

The producing structures of this oil basin are located in a narrow strip between the coast and the steeply folded foothills of the central Sumatra mountain range. The northeast part of this basin lies in the sea. About a dozen fields had produced close to 150 million barrels at the time of the invasion.

The most important field at the time of the invasion was Rantau, with an average daily production of about 15,000 barrels in 1940. Rantau is a rather gentle anticlinal structure. Two systems of faults divide it into a number of fault blocks, the total effect of this faulting being a "caved-in crest." The oil is produced from a section of alternating sands and shales of upper Miocene age. A large number of sands are producing, the most important at depths ranging from 925 to 2,675 feet. The thickness of these sands varies from 10 to 100 feet, and great variations of texture, porosity, and permeability occur. All producing zones, especially the shallow ones, have a more or less extensive gas cap. The volume of the gas cap and the subsea depth of the gas-oil and the oil-water contacts show considerable variation for the different fault blocks. Water-drive as well as depletion plays a part in the production processes.

The structure maps of different formations indicate a gradual slight steepening of the structure with depth, caused by slight thickening of individual beds off structure. On the other hand, it appears that the throw of individual faults does not increase with depth, and in some places it can be observed that faults entirely disappear downward.

The structure is tested to a depth of about 5,600 feet. Below the producing sands a predominantly shaly section was encountered.

Production started at Rantau in 1929 and by December, 1936, more than 24 million barrels had been produced. During 1940 about 140 wells produced 5,707,000 barrels. Nearly all wells were flowing, but a few had to be produced by gas lift. The developed area consists of about 1,000 acres, covering approximately the southeast half of the structure.

The oil of this field and of this basin in general is of excellent quality. Rantau produces to a light paraffinic, highly aromatic oil, with a gravity of 44.4°–51.2° API. The yield of aviation gasoline is as high as 21 per cent, motor gasoline 44 per cent, and fuel oil 30 per cent.

SOUTH SUMATRA

The oil-bearing area of South Sumatra, including Djambi and Palembang, belongs to a separate Tertiary basin differing in many respects from the North Sumatra basin.

In South Sumatra the whole width of the basin is present. The northeastern coastal area, as indicated by the shallow occurrence of igneous rocks, belongs to the continental masses of the Malacca Peninsula. The southwestern limit of this oil basin, as in North Sumatra, is formed by the highly upfolded and complicated structures of the Barisan Mountain range. The oil fields are spread out over the central and southwestern parts of this basin consisting of low rolling hills and swampy plains. They are associated with anticlinal structures which are commonly arranged in well defined anticlinoria. Some of these structures, especially in the southwestern part, are rather steep and asymmetric, the steep flanks being related to thrust faults. Most of the structures also are broken by normal faults into fault blocks which show appreciable differences in the gas-oil and the oil-water contacts. Water-drive as well as depletion-type fields occur.

TABLE II

CRUDE-OIL PRODUCTION, SOUTH SUMATRA

Company and Fields	*Year Production Began*	*Approx. Total Production in Barrels (End of Period Indicated)*	*Production during 1940 in Barrels*	*Type of Oil*	*Depth of Producing Sands (Feet)*
NKPM					
Benakat-Selo	1933	30,000,000 (1941)	3,707,000	Paraffinic	1,400–1,600
Talangakar-Pendopo	1918	99,500,000 (1941)	9,031,000	37° API. Very paraffinic	2,000–3,000
Djirak	1930	17,600,000 (1941)	2,528,000	Paraffinic	750–2,900
NIAM					
Djambi (4 fields)	1923–1935	54,601,783 (1940)	9,617,000	Light paraffinic, 47.0°–48.0° API. In one field shallow heavy asphaltic oil of 22.5° API.	1,000–4,000
BPM					
Kloeang	1914	26,600,000 (1940)	742,000	Light paraffinic	500–2,600
Limau	1928	4,800,000 (1940)	253,000	Heavy paraffinic	5,400
Mangoendjaja		5,000,000 (1940)	1,580,000	Asphaltic, 23.6°–27.7° API.	430–2,000
Soebandjerigi area (6 fields)	1899	65,000,000 (1940)	785,000	Light paraffinic	650–2,600
Talangdjimar	1937	8,300,000 (1940)	3,500,000	27.6° API. Heavy paraffinic	4,300
BPM NKPM and other fields	1898 and later	25,000,000+	1,203,000		
			32,946,000		

The producing sands are upper and lower Miocene in age, belonging to the middle and lower Palembang formation and the Telissa formation. Part of the Telissa oil is obtained from basal Miocene sands and granite wash. In the cores of some structures such as Talangakar, Djirak, and Kloeang, these basal sands and the underlying pre-Tertiary were reached at rather shallow depths, proving that the Miocene is overlapping pre-Tertiary erosional highs of considerable relief. Most of the fields are producing from a number of sands and some from as many as twenty.

Table II shows production figures for the main fields of the area, depths of producing sands, and some data about the characteristics of the crudes. These crudes vary in quality and percentage of higher fractions. In general they have the characteristics of intermediate-base crudes and have a varying degree of wax content. Djambi crudes are relatively wax-free and have more aromatic constituents than the crudes around Palembang.

JAVA

The upper Tertiary facies of westernmost Java can be characterized as transitional between the basins of South Sumatra and Middle Java. Middle and East Java however definitely belong to a separate Tertiary basin, and beds of Paleogene age, in contrast with South Sumatra, are known from West and East Java.

Oil production, so far, is restricted to a relatively small area in northeastern Java. This area has a regional position similar to the oil basin of southern Sumatra as it lites between the highly complicated geanticlinal axis of central Java and the masses of the Asiatic continent. The island of Karimoendjowo, just off the north coast, consists of pre-Tertiary beds. Facies changes in the young Tertiary section, furthermore, clearly indicate that the source area for these sediments was situated not far north of Java, that is, in the area now occupied by the shallow Java Sea.[6]

About a dozen oil fields have produced approximately 110,000,000 barrels, the most important being Kawengan, Ledok, Nglobo, and Lidah-Kroeka. Most of the oil is derived from sandstones associated with a section of *Globigerina* marls of upper Miocene age. In contrast with the producing sands in Sumatra and Borneo, these sands are rather persistent. This no doubt is related with the deep neritic to semibathyal character of the *Globigerina* marl section of Java, while the upper Miocene of Sumatra and Borneo is decidedly neritic or paralic. The production of the Java fields therefore in general is of the water-drive type.

The oil is accumulated in moderately steep anticlines generally intersected by normal faults, and commonly characterized by pronounced asymmetry. The steep flanks are in places associated with thrust faults observable at the surface or revealed by drilling. Interesting observations in this respect have been made in the Nglobo field. This anticline at the surface is gentle with flank dips of about 10°, which, however, in a longitudinal zone in the south flank steepen to about 20°. At a depth of approximately 2,500 feet this slightly steeper zone has developed into a pronounced steep zone connected with a thrust fault of small throw. These observations can not be explained by an unconformity related to a distinct period of folding. Slight folding evidently took place more or less continuously during the deposition of the upper Miocene beds. This is also indicated by detailed surface mapping which revealed facies changes in different formations of the upper Miocene coinciding with the structural configuration.

The oil sands so far are from relatively shallow depths, ranging from about 700 to 3,000 feet. Deeper possibilities in beds of lower Miocene age are indicated by observations made on the island of Madoera, geologically representing the eastern extension of northern Java. Here a predominantly shaly section of lower

[6] Some of the Miocene and Pliocene beds of northeastern Java become increasingly tuffaceous toward the south. This indicates the temporary existence during Tertiary time of volcanic islands or submarine volcanoes in the now geanticlinal central parts of Java.

Miocene age crops out. Oil indications are plentiful but sands, although not missing entirely, are scarce. One small field produced some oil.

The oil of most East Java fields is paraffinic to heavy paraffinic with specific gravities from 35° to 45° API. The paraffine content can change from one field to another from less than 3 per cent to more than 13 per cent within the same producing zone. These sudden changes are difficult to explain. The facies is relatively uniform and also the intensity of folding of the different producing anticlines does not vary much. In some instances, however, it looks as if the paraffine content may depend on the intensity of folding of the accumlating structure.

The Lidah-Kroeka field, situated close to the harbor of Soerabaja, is characterized by relatively heavy asphaltic oil (25° to 33° API). Production is obtained from the top part of the upper Miocene *Globigerina* marls section and from irregular sands within the superimposed Pliocene clays. In this instance, the exceptional type of the oil evidently is related to the age and the type of sedimentation. The Pliocene-Miocene contact, though no angular unconformity can be observed in this area, is slightly unconformable locally, and represents a pronounced change in the type of deposition over the whole basin.

BORNEO

Four areas of the island of Borneo are briefly discussed.

(a) Balikpapan area in Southeast Borneo
(b) Tarakan area in Northeast Borneo
(c) Miri-Seria area in Northwest Borneo (British)
(d) Barito area in South-Central Borneo

Areas *a* to *c* include the oil fields of Borneo which had produced, at the time of the occupation, approximately 500,000,000 barrels. Area *d* is not yet producing, but commercial oil accumulation has been discovered.

BALIKPAPAN AREA

Oil was discovered in this area in 1898, and until the end of 1940 about 240,000,000 barrels of crude were produced. Although this area has contributed more than 20 per cent of the total production of the Archipelago, its 1940 production only amounted to about 10 per cent. This demonstrates that the main fields of this area, Louise and Sambodja, have passed their peak and are on the decline.

Practically all producing structures are part of one huge anticlinal trend, situated between the coast and the highly upfolded, complicated structures of the Meratoes Mountains. These producing structures are moderately steeply folded, are complicated by cross faulting, and are characterized by steep western flanks. Oil is found in sands of upper Miocene age. About ten different sands are producing, the deepest at about 2,500 feet. At shallow depths, these sands contain heavy asphaltic oil; downward, the oil becomes lighter and more paraffinic. It is interesting to note that the character of the oil seems to be primarily a function of the subsea depth of its occurrence and not of its stratigraphic age. In Louise, for in-

stance, sands which near the crest of the structure produce heavy asphaltic oil, produce light asphaltic oil at greater depths down the plunge, or in down-faulted blocks.

TARAKAN AREA

Practically all the oil produced in northeastern Borneo is derived from the island of Tarakan. The backbone of this island is formed by a huge anticlinal structure. Four of the dome-like culminations of this structure contain oil accumulations. By far the most important field is Pamoesian, with a producing area of about 1,100 acres. Djoewata produced from about 40 wells while two domes were hardly commercial. These fields, although covering an area of only about 1,300 acres, have produced more than 145,000,000 barrels, or about 110,000 barrels per acre. During 1941 the daily rate of production was 13,600 barrels. The producing formation is Pliocene and upper Miocene in age and consists of an alternation of sands, conglomerates, sandy clays, and clays with numerous beds of lignitic coal. These coals are persistent and make good markers.

Pamoesian is a rather gentle structure, broken by some normal faulting. Fifteen producing sands have been proved so far. The upper twelve, at depths from approximately 180 to 1,500 feet, are responsible for the bulk of the oil produced. They are characterized by heavy asphaltic oil of about 18° API which can be used directly as a fuel or low-grade diesel oil. The three deepest sands (2,400–3,700 feet) contain a lighter paraffinic oil. Many of the producing sand bodies are thick, and in their lower parts, as a rule, contain salt water over the whole structure. A relatively strong water drive can be observed, and the bottom water tends to cone up under and into the wells. Each layer therefore has to be produced separately and it is the practice to penetrate the oil sands only 20–30 feet. At the time of the destruction of the field before the Japanese invasion, five wells were flowing, thirty were producing by gas lift, and the rest were pumping. Due to the rather advanced stage of depletion reached by this field for the shallow asphaltic oil, water contamination was a serious problem. Most of the oil, however, separates easily from water.

MIRI-SERIA AREA

Production in this area began in 1913 and, until the end of 1940, more than 100,000,000 barrels were produced. Oil is derived from two fields, the Miri field in Northern Sarawak and the Seria field in Southern Brunei.

Miri was discovered in 1911, reached its peak in 1929, and is now approaching the depletion stage. At the time of the invasion (September, 1941) it was producing about 3,000 barrels per day from 350 pumping wells. This field is associated with a rather complex, highly faulted, asymmetric anticline. The southeast flank is steep and complicated by thrust faulting.

Seria, 25 miles north of Miri, was discovered in 1928. At the time of the invasion, besides 11 offshore wells, 140 wells had been drilled on an area 5 miles long, and ¾ mile wide. The field at this time had a daily potential exceeding

43,000 barrels (25,000 barrels light oil, 18,000 heavy oil). Production limits were only partly established, and the field represents one of the largest known reserves in the East Indies.

The Seria field is located on a large east-west-trending anticline, the axis of which lies offshore in the South China Sea. Flank dips are 5° to 15° and in places as steep as 25°. Normal longitudinal faults dipping north at angles of about 45°, with throws of 100 to 900 feet, together with transverse faults, complicate this south flank and control, to some extent, the accumulation of oil. Heavy asphaltic oil of 19° API is produced at shallow depths (500–2,000 feet) from the Seria formation. This formation, upper Miocene in age, has a thickness of 2,500–3,300 feet and consists of alternating sands, sandy clays, and clays. It is underlain by the Miocene Miri formation, characterized by harder clays with sand intercalations. Somewhat more than 3,000 feet of this formation is explored so far. Its sandy zones contain paraffinic oil of about 32° API, which is produced by natural flow. The field is divided into separate reservoir units by the two systems of faults. The size of the gas caps and of the oil-bearing parts of each sand layer may vary considerably from fault block to fault block. Production by depletion appears the universal characteristic.

BARITO AREA

This area is situated in the broad valley of the Barito River west of the geanticlinal Meratoes Mountains.

Oil was discovered in commercial quantities on two structures approximately 100 miles upstream from the harbor town of Bandjermassin. This discovery is of special interest as the producing sands of these structures are Eocene in age, while elsewhere in the Archipelago all production is from Miocene or Pliocene beds. The oil is of medium type, and paraffinic to heavy paraffinic.

CERAM

Outside the large islands of Sumatra, Java, Borneo, and New Guinea, only one field has been developed in the Archipelago. This is the Boela field on the island of Ceram, situated between Celebes and New Guinea.

This field is not large, having produced a total of about 8,000,000 barrels, but is interesting in some respects. It seems very likely that the oil, accumulated in shallow Plio-Pleistocene sands at depths of 200–1,000 feet, is derived from beds of Triassic age, which the young beds overlap. As mentioned before, the Triassic is developed locally in a shaly facies of decidedly petroliferous character.

The Boela oil is heavy asphaltic with a specific gravity of about 22.5° API.

NEW GUINEA

Within the large area (25,000,000 acres) for which the Nederlandsch Nieuw Guinea Petroleum Maatschappij (NNGPM) had obtained an exploration concession in 1934, so far only one Tertiary basin has been evaluated as to its

oil possibilities. This basin covers the southern part of the Vogelkop (birdhead) which is the northwesternmost promontory of this island.

Explorative drilling was started in 1937 in this Vogelkop basin. At the time of the invasion, oil had been discovered on three structures: Klamono in the western and Wasian and Mogoi in the eastern part. Wasian and Mogoi lie close together, approximately 130 miles from Klamono. It is interesting that these structures are the only ones in the whole Archipelago where oil is produced from limestone and not from sands. These discoveries prove that this large basin (about 200 miles long and 40–70 miles wide) offers possibilities for the development of substantial production. Many favorable structures have been mapped in the hilly northern parts of this basin or were found by geophysical work and core drilling below the alluvial cover of the plains and the coastal swamps.

Klamono.—Klamono is a broad dome-like anticline with flank dips of 5° to 10°, broken in blocks by two systems of normal faults. The surface beds are marly shales with a few thin limestones. Numerous oil seeps are present in the axial part of the structure. The drilling of fourteen shallow wells revealed the top of a porous limestone section at depths as shallow as 300 feet near the apex of the structure. Both this limestone and the outcropping shales are upper Miocene in age. The limestone represents a coral reef which is only present on and near the crest of the structure, grading off-structure into marly shales. A period of folding of middle Miocene age is indicated by a widespread unconformity in this area, and the aforementioned facies changes evidently are related to a gentle structure formed by this folding. Eight of the fourteen wells found oil in this reef limestone, proving an area of about 400 acres. Initial daily production of individual wells averaged 1,400 barrels, but was as high as 3,000 barrels. A uniform, horizontal water table is indicated throughout the different fault blocks with a saturated limestone section up to 400 feet thick above it. The Klamono crude is asphaltic, has a gravity of 18.8° API, and can be used as a fuel without refining after a light flashing-off process.

Wasian and Mogoi.—The Wasian and the adjoining Mogoi anticlines in the eastern Vogelkop are part of a large anticlinorium, which trends northwestward and has a length of about 60 miles. Both structures are rather gentle with flank dips of 5°–20°. Mogoi is slightly steeper than Wasian, and has a steep zone in the northeast flank. Both structures are closed at the surface in a predominantly shaly section of Pliocene age. At Wasian two wells were drilled. Both found oil saturation in the top of a limestone section of Miocene age at 3,100 and 3,225 feet. The daily production rate of the second well was 2,400 barrels. No conclusive test was made in the first well which was drilled to about 9,000 feet. The oil is paraffinic and has a gravity of 47.6° API. At Mogoi, the Miocene limestone was reached at 1,873 feet and, according to a preliminary rating, produced 600 barrels per day. It is possible that the producing limestones of Wasian and Mogoi are reef limestones, although they differ lithologically in some respects from the Klamono limestone.

The Wasian and the Mogoi structures were discovered and to a large extent mapped by stereoscopic studies of air photographs. This is rather remarkable as the whole area is covered by dense tropical jungle.

AIR MAPPING

A few words may be added here concerning the air mapping done on an extensive scale by the NNGPM. No maps, except large scale maps and sea charts, were available for most of the area. The whole area therefore, was photographed on a scale of 1:40,000 (1 inch=3,33[illegible] feet). Topographic maps made from these pictures at the same scale formed the base for all further exploration activities. Besides this, systematic stereoscopic studies of the pictures were made by trained photogeologists. These studies made it possible to outline the following areas.

1. Areas of swamps and lowland without outcrops
2. Flat areas more or less unfolded or covered by terraces
3. Areas gently to moderately folded. Most of the anticlinal structures could be outlined in a general way; faults and areas of culminations on the anticlines often could be located
4. Areas of steep, highly upfolded structures

It is evident that, with this information at hand, an efficient planning and organizing of the geological exploration work was possible. This is of special importance in a region where each field party means organizing and fitting-out of a small-scale expedition into more or less unknown jungle country.

Areas of the first two types had to be explored mainly by geophysical methods such as gravity and seismos. The third, generally speaking, represents the area of favorable Tertiary structures (like Klamono, Wasian, and Mogoi), while the fourth type predominantly belongs to the geanticlinal part of the basin with pre-Tertiary anticlinal cores.

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EVOLUTION OF REEF CORALS IN EAST INDIES SINCE MIOCENE TIME[1]

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ABSTRACT

Percentage figures of Upper Tertiary corals in the East Indies are useful as a method of stratigraphic dating and correlation. The percentage of still living species increases in the following order: Miocene 0 to 50, Pliocene 50 to 70, Pleistocene and Holocene 70 to 100. It is argued that the evolution of the reef corals may graphically be represented by a curved line showing two accelerations, one in the upper Miocene, another in the Pleistocene. The possible causes of these epochs of an accelerated evolution are discussed and a comparison is made with the evolution rate of the Mollusca, another group of amply studied marine invertebrates.

During the last decade our knowledge of Tertiary coral faunas in the East Indies has been augmented by the description of suites from several horizons which supplied new data, of importance to stratigraphy. Consequently the present writer has taken up a revision of all data known so far in order to summarize the present state of knowledge on this subject and to show the usefulness of corals in Tertiary stratigraphy. The full data of this revision may be found in a paper, which reviews the stratigraphic sequence of coral faunas in the East Indies from the Eocene to the Pleistocene (to be published in the near future).

One of the questions discussed in that paper at great length is the percentage of still-living species in the suites of Tertiary and Pleistocene reef corals. And it is argued that the stated percentage figures, if critically applied, are useful as a method of stratigraphic dating and correlation.

In Table I a list is given of percentage figures of reef-building corals, as ascertained to the present time.

An approximation of characteristic percentage figures, after the personal equation, statistical, technical, geographic, and other selective factors have been taken into account, is shown in Table II.

In the present paper these results are considered only from a biological point of view. In order to obtain an impression of the rate of evolution we start by plotting on the graph (Fig. 1) a percentage of 70 corresponding with the boundary of Pliocene and Pleistocene roughly 1 million years ago (*A*, Fig. 1).

If we try to complete our graph two difficulties are encountered. In the first place the question arises at what date, in absolute geologic time, should the boundary between Pliocene and Miocene be fixed?

W. D. Urry[3] mentioned the following ages of Tertiary rocks (in millions of years) according to the helium method (Table III).

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[3] W. D. Urry, "Ages by the Helium Method, II, Post-Keweenawan," *Bull. Geol. Soc. America*, Vol. 47 (1936), p. 1218.

TABLE I

Locality	*Percentage of Recent Species*	*Stratigraphic Epochs*	
Talaud	100	Pleistocene or more recent	
P. Bunju, East Borneo	100		
Buton, S. Celebes	85.7		
Wahai, Ceram	80		
N. and E. Ceram	81	Lower Pleistocene	
Niki-Niki, *etc.*, Timor	79		
Upper Kalibeng beds, Java	69	Upper Tertiary *h*	Pliocene
Sonde beds, Java (loc. combined)	68.8		
Sonde beds — Duku Pengkol	68		
Sonde beds — Padas Malang	71.4		
Van Rees Mts., New Guinea	66		
Prupuk Reef, Java	53	Lower Tertiary *h*	
Tjisande Reef, Java	46.6	Tertiary *g*	Miocene
Kabasian River, Borneo	32		
Gelingseh beds, Borneo	25	Tertiary *f* 3	
Tjilang beds, Java	21		
Njalindung beds, Java	19		
Rembang beds, Java	17	?Tertiary *f* 2	
Taballar limestone, Java	11	Tertiary *f* 1	
Progo beds, Java	12		
Radjamandala and Seraju beds, Java	0	Tertiary *e*	
—	—	Tertiary *c* and *d*	Oligocene
Several localities in different islands	0	Tertiary *a* and *b*	Eocene

A lead ratio of 25 m.y. for a Miocene rock from the Tucson Mountains, Arizona, published by Nier[4] fits well into this scheme.

On the other hand, the helium ratios of two upper Miocene sedimentary

TABLE II

	Species Still Living (Per Cent)
Pleistocene to Recent	70–100
Pliocene (Tertiary *h*)	50– 70
Miocene, Tertiary *g**	30– 50
Miocene, Tertiary *f*	10– 30
Miocene, Tertiary *e*	0(?)– 10
Oligocene (Tertiary *c* and *d*)	0–few
Eocene (Tertiary *a* and *b*)	0

* The letter division of the Tertiary in the East Indies is largely based on the distribution of Foraminifera. Tertiary *g* is the *Lepidocyclina*-free part of the Miocene.

[4] A. O. Nier, in *Report of the Committee on the Measurement of Geologic Time* (1938).

rocks found by Barkser, Kapustin, and Potapo[5] are on the low side, namely, a limestone from the Pontian of Koubanka, 8.1 m.y. and a limestone from the Sarmatian of Odessa, Cerkovny yar, 14.5 m.y.

They wrote, however, in their report: "These data should be used with great caution because of the exceptional methodological difficulties of the work and of general imperfection in the methodology itself."

Therefore, these data are left out of consideration. If the boundary between Pliocene and Miocene is placed at about 14 m.y. and the boundary between Miocene and Oligocene at 30 m.y. we may be convinced that the correct figures probably are somewhat higher since helium ratios in general are on the low side as compared with lead ratios.

TABLE III

	Million Years
Pliocene basalt, Steens Mtn., Oregon	13 ± 1
Upper Miocene basalt, Douglas Creek Canyon, Washington	17 ± 1.5
Upper Miocene basalt, Douglas Creek Canyon, Washington	15.5 ± 1
Lower or middle Miocene basalt, John Day River, Oregon	18 ± 1.5
Oligocene basalt, Lower Silesia, Germany	{29 ± 2 34 ± 2
Upper Oligocene columnar basalt, Lower Silesia, Germany	36 ± 2
Early Eocene Tinguaite, Montreal	57 ± 1.5

The second uncertainty is of a stratigraphic nature. For Tertiary *g* has been included in the Miocene and the boundary between Miocene and Pliocene has been placed between Tertiary *g* and *h*. It is, however, impossible to say whether this stratigraphic boundary, though useful in the East Indies, coincides with the limitations of absolute geological age based on rocks from stratigraphic sequences in Washington and Oregon. If, for example, Tertiary *g* or part of it would have to be correlated rather with the Pliocene of Steens Mountain than with the upper Miocene of Douglas Creek Canyon, the result in the accompanying graph (Fig. 1) would be *AB* becoming steeper.

The opposite effect seems very improbable since geologists conversant with the stratigraphy of the East Indies will agree that a shift of the stratigraphic boundary so as to include a part of Tertiary *h* in the Miocene seems out of the question.

When reading the following considerations it is of importance to bear in mind these questions.

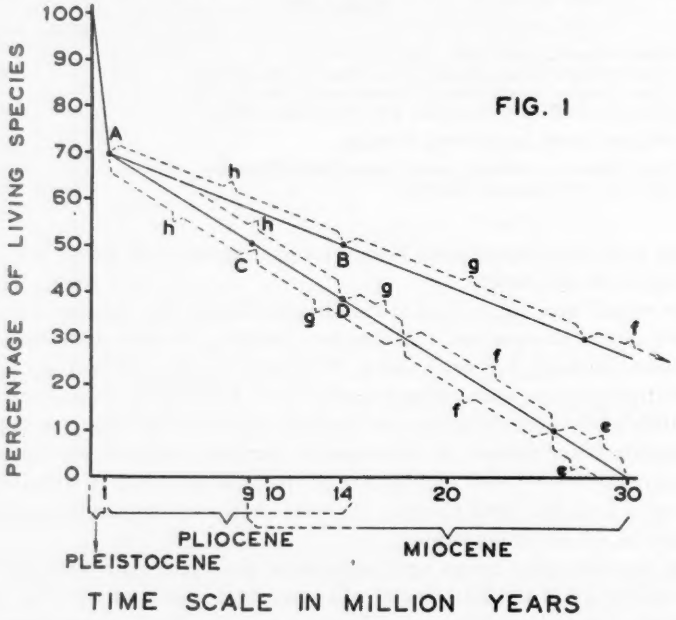
Fifty per cent of living reef corals is the stated figure for the Pliocene-Miocene boundary in the East Indies. If this is allowed to correspond with an absolute age of approximately 14 m.y. the point *B* in the graph (Fig. 1) is obtained.

Now, if it is assumed that the increase of proportion of living species pro-

[5] E. S. Barkser, N. Kapustin, and I. Potapo, "Experiments on the Determination of the Age of Sedimentary Rocks," *Report of the Committee on the Measurement of Geologic Time* (1936).

ceeded with a constant rate from Oligocene to the Pleistocene *A* and *B* may be united by a straight line and continued to the right of *B* till it reaches the horizontal axis of the graph. This point would correspond with about 48 million years of the time scale. This appears to be a much too high figure.

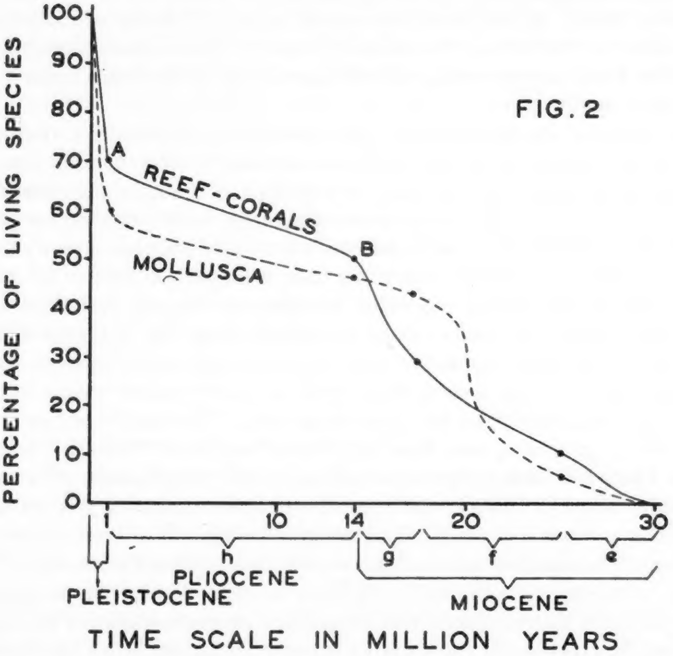
There are but two possible ways to insert the percentage figures along a straight but steeper line within the probable boundary of 30 m.y. for the base of the Miocene, previously deduced. One possibility would be to accept a shorter duration of the Pliocene, approximately 9 m.y. (*AC*, Fig. 1). For reasons previously mentioned, such an assumption can not be justified at present. The other possibility would be simply to accept that the true boundary between Pliocene



and Miocene corresponds with a lower percentage figure, namely, approximately 40 per cent of living species (*AD*, Fig. 1). As already stated, there exists no objection *a priori* to such a supposition. But there are reasons to believe that, instead of a rectilinear evolution, a curved line is more probable. For an undisturbed rectilinear evolution of the coral fauna during the Miocene and Pliocene does not seem probable from a biological point of view.[6] And, moreover, if one accepted a rectilinear evolution for the coral fauna, one would nevertheless inevitably have to admit an evolution of the Mollusca during the same epochs along a curved line—and *vice versa*.

[6] Compare A. M. Keen, "The Percentage Method of Stratigraphic Dating," *Proc. Sixth Pacific Sci. Congress*, II (1940).

Therefore, we shall start over again. If we take the boundary between Oligocene and Miocene at 30 million years and consider 50 per cent as the most probable figure at the Pliocene-Miocene boundary, as suggested in the beginning, the consequence is a curve showing one or more accelerations. Provisionally and tentatively, such a curve is drawn in Figure 2. Moreover, the Miocene and Pliocene epochs, as deduced from the percentage figures of Table II, are indi-



cated by the corresponding letters *e*, *f*, *g*, and *h*. One of the principal differences of this result as compared with a rectilinear sequence is the much shorter duration of Tertiary *g* and the corresponding acceleration of the evolution in that epoch.

Only in time to come when more precise percentage figures and a greater number of determinations of absolute time for Tertiary epochs will be available, will it be possible to construct a curve devoid of the several hypothetical elements which now are inherent to it. In general, however, the curve of Figure 2 seems a better approximation of the real flux of events than a rectilinear sequence. Of course the steeper parts in the curve account only for an acceleration in the number of coral species still living, but it seems highly probable that these epochs coincided with periods of an increased radiation of new coral species (and genera) in general, extinct ones as well as still living forms. One could dwell at some length on this point, but the discussion is restricted to one more aspect of the curve.

Still more marked than the bend in the Miocene is the abrupt break in the line at the boundary between Pliocene and Pleistocene. The explanation can not be sought in an erroneous dating, because an age of no less than approximately 8 million years would have to be assumed for the beginning of the Pleistocene to smooth out the irregularity in the line. That is entirely out of the question. But there is an aspect to the subject of percentage values, of great importance, that must be emphasized. Our knowledge of the recent fauna is naturally not complete. Hence, the line should in point of fact not be drawn to 100 per cent on the ordinate for the recent, if our aim is to trace the fluctuations in evolution, but to a lower figure corresponding with the percentage of the living fauna that has been discovered to date.

The mistake thus introduced is aggravated by the obvious fact, that in many cases the facies from which the fossils are obtained is different from that, which has been most exhaustively studied by biologists. Although some valuable work has been done with diving helmets and dredgings, to all practical purposes our knowledge is mainly restricted to beaches and areas within reach by wading. The fossils, on the other hand, are commonly from lower parts of the reef or from localities where sedimentation proceeded intensively. Beaches, reef flats, and the upper rims of reefs are scarce among studied localities. The influence of facies on the established percentage figure may be illustrated by a short discussion of an extreme case, in which a coral fauna from especially turbid waters was found, resulting in an abnormally low percentage value. The present writer studied a collection of 40 coral species from the lower Pleistocene Putjangan beds (East Java). Twenty of these (50 per cent) belong to still living species. (The collection is not mentioned in Table I, which pertains to suites consisting predominantly of true shallow-water reef corals). This remarkable figure is at least 25 units below the figure to be expected for an adequate collection of lower Pleistocene reef corals. For 69 to 70 per cent is the well established figure for corals from the upper Pliocene Sonde and Kalibeng beds. Consequently, a percentage figure of at least about 75 might be expected for the lower Pleistocene Putjangan beds. The explanation has to be sought in the facies of this remarkable coral faunula. It is not a true reef-building fauna, but a biocoenose of corals which could stand severe conditions of strong sedimentation prohibitive to the growth of reef corals in general and unfavorable to the formation of a reef. Indeed, there is no question of a patch reef as in Prupuk, or of lenses of reef limestone as in Sonde. The collection comes from thin marine intercalations in a complex of volcanic breccias. The special character of the coral fauna is well established by the abundance of solitary and "deep-water" corals belonging to the groups Turbinolidae, Eupsammidae (Balanophyllia, Dendrophyllia, Heteropsammia, Endopachys), Oculinidae (Cyathohelia), and Astrangidae. These are represented by hundreds of specimens. In strong contrast to this, the remainder of the species are represented by one or a few specimens only. It is well known that the turbinolid, eupsammid, oculinid, and astrangid corals thrive either in greater depths of the sea or in shallow seas under conditions

adverse to most shallow-water corals that build up the reefs. Evidently the corals of the Putjangan beds lived under circumstances acting in a selective manner and the writer suggests that the principal controlling factor must have been lack of sunlight. The much disturbed, shallow and muddy waters giving rise to a biotope which in respect to dimness was comparable with conditions in deeper water. A few true reef corals, which apparently could stand this special biotope, settled down here too. Among these we see a few well known shallow-water corals, which have to be considered as more eurytope. But presumably a greater number of corals living in the deeper part of a reef found conditions analogous to their ordinary habitat. Now our present knowledge of living corals is principally based on collections from the upper parts of the reef. As yet the deeper part of a reef was only very exceptionally examined by using a diving helmet. And our actual knowledge of the deep-sea corals is based on a limited number of deep-sea expeditions. The logical consequence is that in case a suite of fossil corals derived from a Miocene or more recent reef be compared with the living fauna, a much higher percentage figure will be found than if a coral suite of equal age but containing many deep-sea forms be compared with the Recent fauna. According to the writer's opinion, there is not the slightest doubt that this explains the low percentage figure of the corals from the Putjangan beds. Undoubtedly we must always allow the possibility that corals described as *species novae* may later be found in the Recent fauna. But, in the case of the special coral facies-type of the Putjangan beds, their number is especially high, much higher than if we were dealing with a true reef-building fauna of equal age.

In short, one may safely conclude that the steep incline of the curve of Figure 2 since the Pleistocene is caused in part by our poor knowledge of the Recent coral fauna, especially of the corals inhabiting the deeper parts of the reefs.

Probably, however, still another factor finds its expression in the abrupt steepening of the curve at the boundary of Pliocene and Pleistocene.

For the Pleistocene is characterized by an intense evolution of the reef-building corals which dominate in the Recent fauna, and in this respect the porose corals, such as *Acropora* and *Porites*, rank among the first, side by side with a strong unfolding of astraeid corals.

As Lull said: " . . . changing environmental conditions stimulate the sluggish evolutionary stream to quickened movement."[7]

Regarding the environmental factors responsible for the accelerated evolution which finds its expression in the steepness of the Pleistocene part of the curve, the exceptionally intensive geographic (and climatic) changes which are so characteristic of the Pleistocene need only be called to mind. Many examples of a strongly accelerated evolution of flora and fauna might be given.[8] Probably the East Indies were at that time only slightly influenced by climatic changes, but

[7] R. S. Lull, *The Evolution of the Earth*. Yale Univ. Press (1919).

[8] J. H. F. Umbgrove, *The Pulse of the Earth*, especially Chapter VIII, pp. 146–50. Nijhoff, The Hague (1942).

the geographic changes were very intense. It is in the Pleistocene that mountain building (in the geographical sense) took place over vast areas, whereas at the same time the many deep sea basins came into existence.[9] It seems probable to a high degree that we may look upon these events as the principal factor which stimulated the plastic group of corals to an intensive acceleration of their evolution; the more so, as the same epoch wrought great geographical changes over the whole of the tropical area of the Indo-Pacific.

Concerning the other epochs showing a quickened movement in the evolution

TABLE IV

Locality	*Percentage Figures*		*Tertiary Epochs*	
	Reef-Building Corals	*Mollusca*		
Ceram	81	—	Lower Pleistocene	
Timor	79	—†	Lower Pleistocene	
Putjangan beds, Java	—*	67	Lower Pleistocene	
Atcheen, N. Sumatra	71.4	56	Tertiary *h*	Pliocene
Sonde, Java	69	53	Tertiary *h*	Pliocene
Tji Djurei, Java	—	51	Tertiary *h*	Pliocene
Prupuk, Java	53	—	Tertiary *g*	Pliocene
Tji Sande, Java	46.6	—	Tertiary *g*	Pliocene
Tji Odeng, Java	—	42	Tertiary *f* 3	Miocene
Tji Lanang, Java	21	33	Tertiary *f* 3	Miocene
Njalindung, Java	19	18	Tertiary *f* 3	Miocene
Rembang, Java	17	16.9	Tertiary *f* 2?	Miocene
Progo, Java	12	8	Tertiary *f* 1	Miocene

* No percentage figure of a true reef-coral fauna available.
† Percentage figure of Mollusca by Tesch: 89%, by Koperberg 85%.

of the Tertiary coral faunas as suggested by the graph, other well known periods of diastrophism in the Miocene[10] might be referred to. But the hypothetical character of the curve should not be forgotten and therefore, this problem is left at this.

As a last point, a comparison is made between the stated rate of evolution of the reef corals and the evolution of another amply studied group of marine animals, namely, the Mollusca.

In Figure 2 the broken line is based on the percentage figures of the marine Mollusca as stated by K. Martin on the strength of his life-long studies of the group.[11] The personal equation (species concept) is to be regarded as the principal

[9] J. H. F. Umbgrove, "On the Time of Origin of the Submarine Relief in the East Indies," *Compt. Rend. Congr. Internat. de Geographie* (Amsterdam, 1938).

[10] J. H. F. Umbgrove, "Geological History of the East Indies," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938) p. 1.

[11] K. Martin, "The Age of the Tertiary Sediments of Java," *Proc. First Pacific Sci. Congress*

factor to which the generally lower figures of Table II for the mollusks are due as compared with those for contemporaneous coral faunas. Consequently, the discrepancies grow larger as more recent horizons are considered. But on the other hand, one of the principal differences consists in the occurrence of the accelerated part in Tertiary *f* for the mollusks instead of in Tertiary *g*, as is the case with the corals. Table IV shows that the Njalindung and Tji-Lanang beds of Java yielded very different percentage figures for the Mollusca, whereas there exists hardly any difference in the figures based on the corals of the same beds. (The percentage figures of Martin's mollusks (Table IV) are all based on large collections and belong to the best established ones.)

The difference for the Mollusca forms contrast also to the similarity of the foraminiferal contents of the Njalindung and Tji-Lanang beds. This remarkable discrepancy between the curves of mollusks and corals may be a biological problem. And then we might ask what caused an acceleration of the evolution in the Mollusca at an earlier epoch than in the corals?

But in connection with this point, it should be borne in mind that the irregularities in the lines for corals and mollusks toward the close of the Miocene may in part be caused by one of the localities being closer related to the beach facies than the other, thus obtaining a somewhat higher percentage value. Further investigations may be hoped to clear up this problematic question.

(Honolulu 3, 1921). The percentage figures mentioned in that paper had to be readjusted in connection with more recent studies by Martin (*Wetensch. Meded.*, 4 (1926), *ibid.* 10 (1928), and *Leidsche Geol. Med.*, 3 (1928). In order to avoid difficulties inherent to the personal equation, no figures for Mollusca are mentioned in Table II other than stated by Martin himself.

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FORMATION OF HYDROCARBONS FROM FATTY ACIDS BY ALPHA-PARTICLE BOMBARDMENT[1]

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ABSTRACT

In the experiments described, four members of the saturated fatty acid series are bombarded by the alpha particles from radon and its active deposit. The energy from the radiation causes principally chemical reaction resulting in formation of carbon dioxide and the paraffine hydrocarbon corresponding with the long chain of the fatty acid bombarded. Minor reactions produce hydrogen, methane, and unidentified material of complex nature. Quantitative studies of the reaction of palmitic acid ($C_{15}H_{31}COOH$) producing n-pentadecane ($C_{15}H_{32}$) indicate maximum yield to be one molecule of the hydrocarbon to 56 electron volts expended by the alpha particles in the material.

This efficiency is theoretically low. The explanatory mechanism is simple. All of the molecules of the fatty acid are activated during bombardment to a state of high excitation. Some decompose by rupture of the carboxyl bond and a hydrocarbon is produced. Some lose hydrogen by breaking of a C-H bond in the long chain. A few decompose to give methane or minor products. Decarboxylation is the preferred reaction, but dehydrogenation always takes place.

The source of free saturated fatty acids in marine organisms and sediments is discussed. Few analyses are available, but fatty acids appear to range from 0.2 to 5 per cent of the organic content of marine bottom muds.

On the basis of these figures, the yield of the hydrocarbon during bombardment, and the radioactivity of the Antrim shale in Michigan, calculation is made of the possible contribution to petroleum from hydrocarbons formed from fatty acids by alpha particles in 10 million years. The result, 6.8×10^{-4} gram of hydrocarbon per gram of sediment or about 208 barrels of crude oil per acre foot of shale, is to be accepted with some caution on account of the assumptions made.

INTRODUCTION

Since the time of Newberry and Orton, geologists have sought the origin of petroleum in complex organic substances deposited with sediments. Transformation of such materials to the hydrocarbons characteristic of crude oils requires some process resulting in reduction of their primary content of oxygen, nitrogen, phosphorus, and sulphur. Various sources have been proposed to provide energy for the chemical reactions producing these changes.

Early research, chiefly by chemists, utilized heat as the source of energy. Hydrocarbons were synthesized by pyrolysis at high temperatures from many substances of both animal and vegetable derivation. Geothermal studies in oil fields, however, indicate that petroleum has commonly been formed at low temperatures. Pyrolytic conversion of organic materials to petroleum is not possible in the laboratory at such temperatures. It may still conceivably proceed at ex-

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The writers gratefully acknowledge the advice and encouragement of all the members of the advisory committee, of W. J. Mead, director, and Clark Goodman, physical director of this division of the Project. A. A. Morton of the department of chemistry, Massachusetts Institute of Technology, frequently offered helpful chemical information. Part of the laboratory work was done by Miss Virginia L. Burton. W. E. Hanson of the Mellon Institute has made a number of valuable suggestions on analytic procedure. Especial recognition is due the Deaconess Hospital of Boston for the radon used in bombardments.

tremely slow rates over geologic periods of time, but is regarded with some doubt as an effective process in the formation of many crude oils.

On this account attention was turned to more exact studies of pyrolysis and to other possible sources of energy. Decomposition of the organic constituents of certain sediments was studied at varying temperatures under the microscope by using the microfurnace. The effect of high shearing pressures on organic shales was investigated and research was begun in an attempt at bacterial conversion of organic substances to hydrocarbons. These three projects were sponsored by the American Petroleum Institute (1)* and were completed without conclusive solution of the problem.

In recent years new interest has been aroused in the role of bacteria in the formation of petroleum by the discovery of marine bacterial oxidation of hydrocarbons (2, 3). This discovery casts some doubt on the conclusion of Trask that recent organic sediments are low in hydrocarbons, for hydrocarbons might have been consumed by bacteria between the times of collection and analysis of samples. The negative results of the earlier work on bacterial synthesis of higher hydrocarbons is also similarly made subject to possible revision. Mixed strains of bacteria used in these experiments might have contained the hydrocarbon oxidizing types.

In consequence, the whole subject of petroleum genesis has been reopened for examination. Synthesis of hydrocarbons by both bacteria and by other plants appears worthy of renewed investigation. The appreciable radioactivity of certain sedimentary rocks and associated petroleum (4) presents another possible source of energy for the reactions of organic conversion. After thorough review of the problem, the American Petroleum Institute established Project 43, Transformation of Organic Material into Petroleum, in three divisions (5): (a) Bacteriological and Sedimentation Phases, (b) Chemical and Biochemical Phases, and (c) Physical and Physicochemical Phases. The present investigation has been done under the last, Project 43c.

ALPHA-PARTICLE BOMBARDMENTS

The radioactivity of terrestrial materials comes essentially[4] from elements of the uranium and thorium series and from potassium. These atoms are characterized by spontaneous disintegration; the atomic nucleus is unstable and decays to form a daughter element.

In the decay series, the disintegration starts with an original element, uranium or thorium, and proceeds by a number of transformations to the final stable end-product, lead. Each active member of the series always disintegrates to form the atom of its daughter substance and emits typical radiation. Certain atoms emit only beta particles, high-velocity electrons. Others always emit alpha par-

* Numbers in parentheses refer to bibliography at end of this paper.

[4] As actino-uranium has an abundance of only 0.7 per cent of total uranium, its series is of minor importance. Rubidium and samarium seldom contribute significant amounts.

ticles, helium nuclei traveling at high speed. Immediately following the emission of an alpha or beta particle, a nucleus may also emit the highly penetrating electromagnetic radiations of gamma rays.

The radioactivity of potassium presents some complexity. The rare isotope, atomic weight 40, has a normal beta activity and decays to the most abundant isotope of calcium. It also emits gamma rays, but not as an accompaniment of the beta transformation. Instead, this gamma ray appears to result from the capture of an orbital electron by a potassium nucleus. The decay product of this change is believed to be argon.

Potassium is the commonest radioactive element, but its contribution to the energy of radioactivity in normal rocks is less than that from the uranium and thorium series. Potassium has a slow rate of decay, low relative abundance of the active isotope and lower energy of the beta and gamma rays compared with that of the alpha particles from the two decay series.

Alpha particles.—The alpha particle is composed of two protons and two neutrons bound together as in the nucleus of helium. Emission from the radioactive element is at very high velocity. Because of the relatively heavy mass of these rays, they can penetrate solid surrounding matter only a few tens of microns, about the thickness of a sheet of paper, or surrounding gas under normal conditions a few centimeters. During this absorption the energy of the alpha particle is converted to molecular excitation, ionization, and finally to heat.

Alpha particles account for about 89 per cent of the energy liberated in the uranium and thorium series. If the normal contribution from the beta and gamma activity of potassium is included, the proportion of energy from alpha particles in rocks is reduced to about 75 per cent. They constitute, therefore, the radiation of dominant interest in the study of chemical reactions caused by radioactivity in the geological environment.

Source of alpha particles.—Eight alpha particles are produced in the transformation of an atom of uranium and its succeeding elements through the series to a stable atom of lead. Each of the eight elements decaying with alpha radiation emits particles of characteristic energy. Similarly a thorium atom and its series gives rise to six alphas of different energies. On this account the effects caused by alpha particles from the fourteen sources in the two series vary somewhat, but this variation between alpha particles is small compared with that between these particles and beta or gamma rays.

Nevertheless, it might seem desirable to use the entire series of radioactive elements to obtain particles for experimental purposes except for other factors. First, the members of the series are in equilibrium in unweathered rocks of Pliocene age or older.[5] The elements exist in concentrations of constant ratio and the

[5] Equilibrium exists in the series when the rate of production of a given element is equal to its rate of decay. An analogous situation is in a reservoir when inflow equals outflow. A state of equilibrium will be attained in time if all members of the decay series are retained *in situ* in the rock. Disturbance of equilibrium is ordinarily caused by migration of the gases radon and thoron.

effect of the alpha particles from the entire series in such rocks can be calculated from the results of experiments with the particles from any one element. Again, the rate of emission varies inversely with the life of the decaying element. Uranium I and II, ionium and radium have long lives and emit alphas slowly, but the daughter element of radium, the gas radon, has a half-life of only 3.8 days. Following an exponential law of decreasing activity, the initial activity of this element has declined to a negligible level within about 30 days. The decay rate

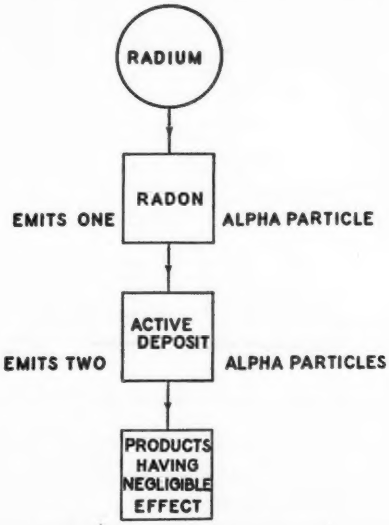


FIG. 1.—Radium and decay products.

is not so rapid as to make measurement difficult and thus complicate introduction of a known amount of radon into the bombardment vessel. Chemical work on bombarded material is postponed until the dangerous initial activity of the quantities used has practically ceased. The corresponding element of the thorium series, thoron (half-life 57.5 seconds), has a much faster decay rate than radon and is unsuitable for experimental use.

The elements succeeding the gas radon in the decay series are solid substances. The first five are very short-lived and each breaks up almost immediately to form another element. The resulting complex of immediate atomic products from the decay of the original radon is called the "active deposit" (Fig. 1). Among the elements in the active deposit are two which emit energetic alpha particles. The elements following these first five in the series disintegrate at an extremely slow rate. They have a negligible effect in the present research.

Radon is readily available for experimental work at reasonable cost. It is used for medical treatment and at times certain hospitals have an excess above their

requirements. The gas is separated from its parent radium and introduced into small "needles" made of thin-walled glass capillary tubing. It was furnished to the project in this form.

Method of bombardment.—The exact research by Lind and others (6, 7) was done on the chemical effects of alpha particles in gases. Radon and the gas under bombardment were mixed together in a spherical vessel. Formulae were developed for determining the action of the radon in the mixture of gases. In the first work of this project, similar studies (5, pp. 131–132; 8) were made of the reactions

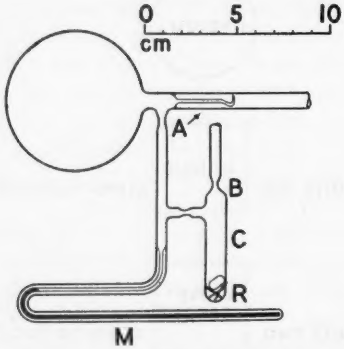


FIG. 2.—Bombardment vessel and device for introducing radon.

in gaseous hydrocarbons caused by alpha particles from radon and the earlier results were confirmed. Before the present investigation, no quantitative bombardments had been attempted on solids.

The fatty acids used in these experiments, except acetic acid, are solids at the temperatures of bombardment. The best procedure found was to coat the melted substance on the inside of a container, cool to solidification, evacuate the vessel and introduce the radon. The gaseous radon then occupies the interior volume and the atoms of the active deposit, as they are formed, migrate to the walls. A large fraction of these atoms finally coats the inner surface of the lining of solid material.

The alpha particles, both from the radon and from any active deposit still distributed through the radon, encounter negligible opposition in their travel through the essentially empty volume of the container at the beginning of bombardment. They are, therefore, free to bombard a thin layer of the solid coat on the wall. The thickness of this film is about equal to the maximum distance of penetration by the alpha particles. If a spherical bulb is used, a correction can be made for the fraction of the energy of the alpha particles used up in later stages of the bombardment as they traverse the gaseous products of reaction which accumulate in the bulb.

The glass bulb (3.8 cm. radius) used in bombardments has a volume of about 220 cc. (Fig. 2). The material to be bombarded is coated on its interior. The stem

is provided with a closed "hook seal," A, of thin glass tubing which may be broken by a magnetic plunger at the time of analysis.

The radon needles, R, are inserted into the side chamber, C, through the evacuation tube, B. The system is then evacuated to a pressure of less than 1 mm. of mercury and the constriction at B sealed. By careful shaking, the glass radon needles are broken under the impact of the glass pellet at R. The side

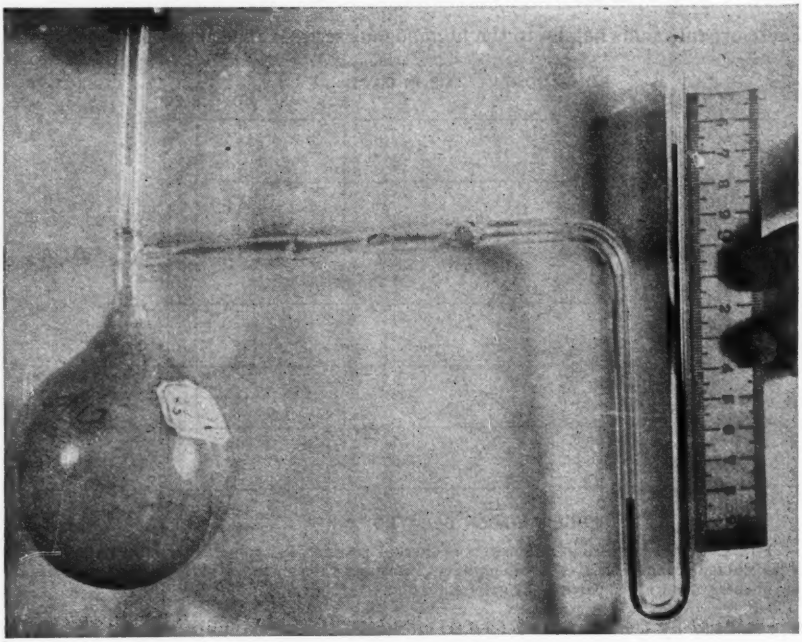


FIG. 3.—Typical alpha-particle bombardment. Pressure of evolved gases as shown on manometer at right.

chamber is then heated to assist the movement of radon into the larger volume of the main bulb. A relatively small part of the radon remains in the side chamber. Lastly the side chamber is sealed off and bombardment proceeds until the radon has decayed to a negligible activity.

In quantitative experiments, the pressure of the gaseous products is measured (Fig. 3) at intervals by the manometer, M. Measurements also are made with a Geiger-Müller counter of the activity of radon needles at the beginning of bombardment and of the bulb at various periods by comparing their gamma-ray activity with that of a known amount of radon in equilibrium with its parent radium. From these data, production of gas is related to the decay of radon

(Fig. 4) and yields of reactions, per unit energy expended by the alpha particle, may be calculated.

PRODUCTS OF BOMBARDMENT

In the researches described here, bombardments were made on

Acetic acid	CH_3COOH	Melting point 17°C.
Caprylic acid	$CH_3(CH_2)_6COOH$	16
Lauric acid	$CH_3(CH_2)_{10}COOH$	43
Palmitic acid	$CH_3(CH_2)_{14}COOH$	64

These organic acids belong to the homologous series, called fatty acids, generally

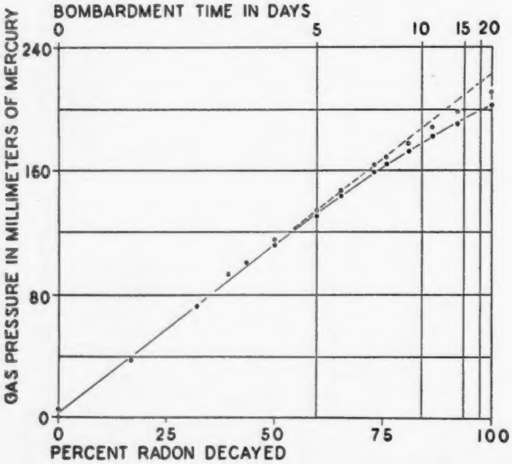


FIG. 4.—Total pressure in millimeters of gaseous products in typical bombardment as function of percentage of radon decayed. Dots represent measured values; circles, value corrected for absorption of energy from alpha particles by gaseous products.

represented by the formula RCOOH in which the carboxyl group has the struc-

ture $-\mathrm{C}{\overset{\displaystyle /\!\!/ \mathrm{O}}{\underset{\displaystyle \backslash \mathrm{OH}}{}}}$. The group R may be a straight chain, alkyl group as in the saturated fatty acids, an unsaturated group, or a complex branched group.

Bombardments to date have been confined to saturated acids. Acetic acid was bombarded in the gas phase (130°C.). In other experiments, where the inside of the bombardment vessel is coated by a film of the acid, only acids solid at convenient temperatures have been investigated.

Analysis of gases.[6]—After the radon has decayed during bombardment to

[6] Detailed discussion of methods of analysis for both gases and liquids will be published in a paper now in preparation.

negligible activity, a determination is made of the pressure, volume, and temperature of the gas which has accumulated in the vessel. The apparatus (Fig. 5) in which these measurements are made is also used to transfer the gas to the analytical apparatus (Fig. 6).

A certain fraction of the pressure, which is measured by the manometer (A,

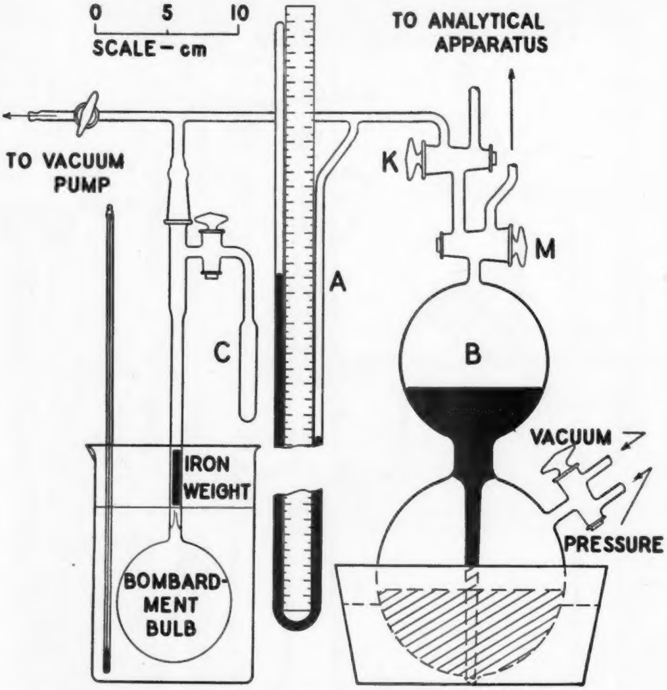


FIG. 5.—Apparatus for measuring gaseous products, separating condensable constituents and transferring gas to analytical apparatus.

Fig. 5) and by the bombardment manometer, results from products which are ordinarily liquid at room temperature, but which have an appreciable vapor pressure. In the present experiments such products are of insufficient amount to form a condensed phase in the bombardment bulb and they remain in the gas. Upon raising the pressure to atmospheric for transfer to the analytical apparatus, their relative humidity increases to 100 per cent and condensation occurs in the Töpler pump (B, Fig. 5). The amounts of these condensable gases are indicated only in the analysis of gases from palmitic acid (Table I).

The gas, non-condensable at atmospheric pressure and room temperature (25°–26°C.), is analyzed by the following procedure.

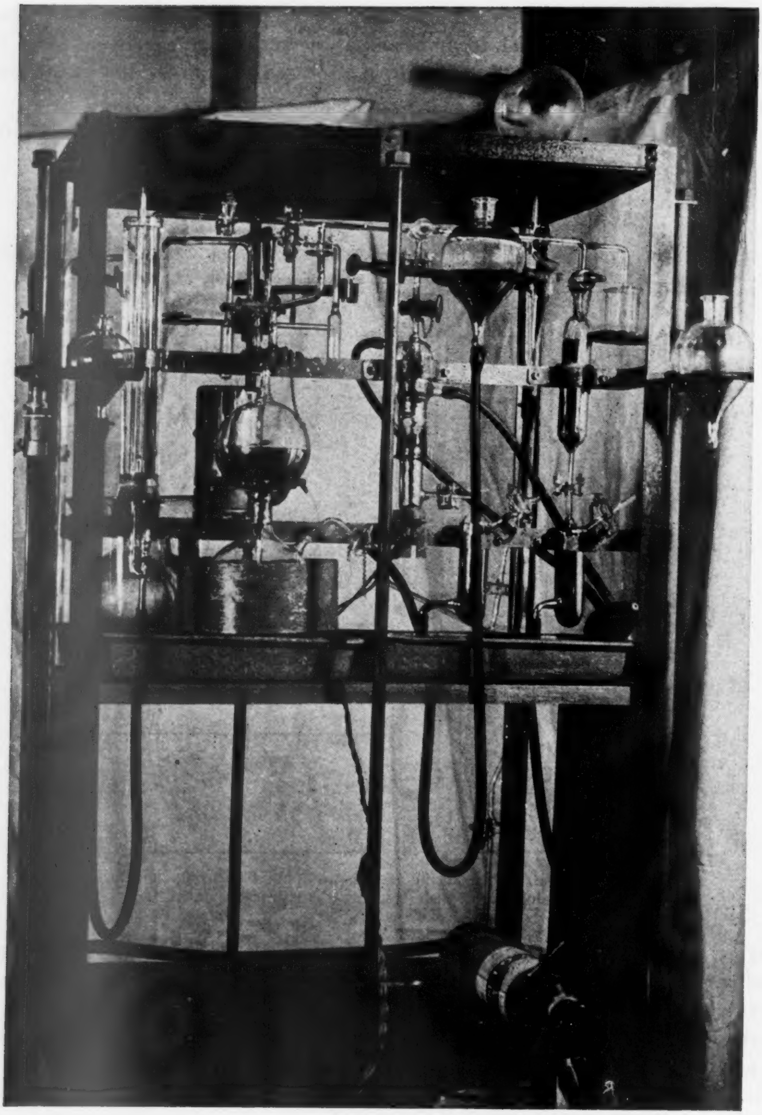


Fig. 6.—Apparatus for analysis of gaseous products.

Absorbed by KOH	Unabsorbed by KOH			
	Condensed by Liquid-Air	Uncondensed by Liquid-Air		
		Absorbed by Cosorbent	Burned with Excess Oxygen	
Carbon Dioxide	Not identified	Carbon Monoxide	Hydrogen	Methane

Confirmatory tests are made to prove that all the gas absorbed by KOH is carbon dioxide.

The residual fraction left in the liquid-air trap is very small in amount; neither a quantitative experiment nor a positive identification is possible. Nevertheless, this fraction was found, in the product of palmitic acid, to react explosively with oxygen and to be partially unsaturated.

The remainder of the gas, after repeated absorptions with "Cosorbent," is burned and determinations are made of the volume contraction after combustion and of the amount of carbon dioxide produced. From the results, the percentages of hydrogen and methane are computed.

Gaseous products.—The compositions of the gases after the various bombardments are given in Table I.

TABLE I
GASEOUS PRODUCTS FROM BOMBARDMENTS
(Percentage by Volume)

	Acetic Acid	*Caprylic Acid*	*Lauric Acid*	*Palmitic Acid*
Non-Condensable				
Hydrogen	17	33	43.1	53.3
Carbon dioxide	36	51	41.9	37.8
Carbon monoxide	20	9	13.6	5.5
Methane	22	4	0.4	1.9
Unknown	5	3	1.0	1.5
	100	100	100.0	100.0
Condensable				
Water vapor	—	—	Present	Present*

* Amount about 10 per cent of total gas; no other condensable constituents found.

Procedure with residue.—Analyses of the products contained in the residue on the walls of the bombardment bulb have been completed as yet only on the materials from lauric acid and from palmitic acid. The procedure is tedious and precise; measurements are time-consuming.

After the gas is removed and analyzed, the bombardment bulb is opened to the air and the material on the walls is treated with hot distilled water. The ex-

tract is titrated with NaOH (0.01 N) to determine water-soluble organic acids.

The residue is then placed in a small high-vacuum still at a bath temperature of 195°C. About half of the liquid product from a typical bombardment is recovered in this way.[7]

After distillation, the remainder of the fatty acid and its converted product is

TABLE II

LIQUID PRODUCT FROM LAURIC ACID

(Properties Compared with Those of Known Hydrocarbon)

	Liquid Product	*n-undecane* (17)
d_4^{20}	0.730	0.7402
n_D^{20}	1.4178	1.4173
$n_F^{20}-n_C^{20}$	0.0072	0.0070
B.P.°C.	195.5	195.8
M.P.°C.	−26.3	−25.6
Double bonds per molecule	0.02	0

TABLE III

LIQUID PRODUCT FROM PALMITIC ACID

	Liquid Product	*n-pentadecane*	(17) *n-tetradecane*	(17) *n-hexadecane*	(17) *l-hexadecene*
d_4^{20}	0.7670	0.7689	0.7632	0.77335	0.7827
n_D^{20}	1.4323	1.4326	1.42886	1.43435	1.4441
$n_F^{20}-n_C^{20}$	0.0081	0.0076*	0.0075*	0.0076*	0.0084
%C	84.6	84.8	84.8	84.9	85.6
%H	15.4	15.2	15.2	15.1	14.4
Mol. Wt.	209	212.2	198.2	226.2	224.2
B.P.°C.	273.5	270.5	253.5	286.5	275
M.P.°C.	7–8	10.1	5.5	18.14	4.06
Double bonds per molecule	<0.03	0	0	0	1

* A characteristic of the paraffine series of hydrocarbons is that the value of the quotient, dispersion divided by density, lies between 0.0097 and 0.0100. Dispersion may be calculated with considerable accuracy from density.

dissolved in pure ethyl ether. The acid is saponified and removed as the sodium salt; the ether is then evaporated by gentle application of heat and the liquid product is distilled again at 195°C. The residue is several milligrams of an amber vaseline-like substance.

Identification of liquid products.—A very small amount of liquid (0.1 cc.) is obtained from the products of the bombardments and isolation of further fractions by distillation is impractical. Fortunately the physical properties of the liquids from both lauric and palmitic acids indicate them to be nearly pure compounds (Tables II and III). The properties determined include the following.

Density (d_4^t).—The specific gravity of the liquid, measured usually at $t = 20$°C., referred to the density of water at 4°C.

Index of refraction (n_D^{20}).—Refractive index at 20°C. with sodium light, $D = 5{,}893$ Ångstroms mean wavelength.

[7] Blank distillations were made on both lauric and palmitic acids before bombardment in order to test for purity. No liquid was obtained in these runs.

Dispersion ($n_F^{20}-n_C^{20}$).—Difference between the refractive indices at wavelengths 6,563 and 4,861 Ångstroms measured at 20°C.
Percentages of carbon and hydrogen (%C, %H).—Determinations by standard methods of combustion analysis.
Molecular weight (Mol. Wt.).—Determinations by the Rast method (9, 10) from depression of the melting point of camphor.
Boiling point (B.P.°C.).—Measurements checked against naphthalene, B.P. 218°C.
Melting point (M.P.°C.).—Determinations by standard capillary tube method with calibrated thermometer.
Olefinic unsaturation (Double Bonds per Molecule).—Measured by catalytic hydrogenation by using special apparatus constructed by N. A. Milas.

The properties of the C_{14} to C_{16} hydrocarbons are included in Table III to show the extent of their change from one compound to another. The similarity of the unknown liquid product to n-pentadecane is striking. This hydrocarbon is

TABLE IV
PHYSICAL PROPERTIES OF N-PENTADECANE

	Krafft	*Panicker et al.*	*Badin*	*Francis*
d_4^{20}	0.7689	—	0.7678*	0.7688
d_4^{28}	—	—	0.7644	—
n_D^{20}	—	1.433*	1.4326*	1.4323
n_D^t	—	1.431[1]	1.4318[2]	—
B.P.°C.	270.5	—	—	270.98
M.P.°C.	10.1	10	—	—

* Values calculated from those measured at other temperatures than 20°C., by using the formulas given by Francis:

$$\frac{dd_4}{dt}=0.0019\,(1.13-d_4^{20}) \quad \text{and}$$

$$\frac{dn_D}{dt}=0.58\,\frac{dd_4}{dt}$$

[1] $t=25$°C.
[2] $t=22$°C.

clearly indicated to be of especial interest. Discussion of former determinations of its properties (Table IV) is in order before considering the identity of the unknown.

The density, boiling point, and melting point determined by Krafft (11) were measured on a sample of n-pentadecane prepared by careful synthesis. It is likely, therefore, that these figures are reliable. The compound studied by Panicker and his co-workers (12) was obtained during their investigations of essential oils. It is assumed to be n-pentadecane, but conclusive proof is lacking. Badin (13) recently prepared a hydrocarbon which in all likelihood is n-pentadecane. The data of Francis (14, 15, 16) were obtained from a series of empirical expressions developed for calculating the physical constants of the higher paraffine hydrocarbons.

The over-all agreement between the physical properties of the unknown liquid and those of n-pentadecane is satisfactory. The presence of aromatic rings should cause the density and refractive index to be appreciably higher than for the paraffine in this molecular weight range. The low value of the dispersion indicates that the molecule does not contain aromatic rings. The combustion data lend

further support to this conclusion, since the percentage of hydrogen in the unknown is larger than in aromatic compounds. The carbon and hydrogen agree with an absence also of naphthene rings in the molecule. These would lower the hydrogen and raise the carbon.

The percentage of hydrogen (15.4) is higher and of carbon (84.6) correspondingly lower than for an olefine. The resistance to hydrogenation is further conclusive evidence for the saturated character of the unknown liquid.

From the molecular weight it is seen that the liquid contains fifteen carbon atoms rather than the fourteen of n-tetradecane ($C_{14}H_{33}$) or the sixteen of n-hexadecane ($C_{16}H_{34}$). The molecular weight and density are slightly lower than these properties of n-pentadecane, but the differences are within the usual probable error of the measurements. The differences of boiling point and melting point, however, indicate the presence of some impurity, probably traces of palmitic acid.[8] It is concluded, therefore, that the liquid product from palmitic acid is nearly pure n-pentadecane ($C_{15}H_{32}$).

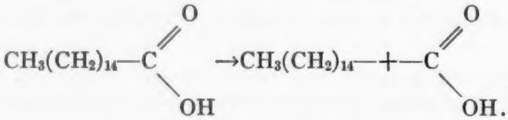
REACTIONS DURING BOMBARDMENT

Analyses were made of the products from seven bombardments of palmitic acid in order to identify with some certainty the hydrocarbon and the gases formed by the effect of the alpha particles. The bombardments of other acids served to confirm the conclusions from these quantitative studies.

Decarboxylation.—The reaction of principal interest takes place by the rupture of the bond between the carboxyl group and the alkyl group.

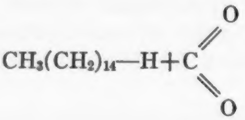
$$RCOOH \rightarrow R + COOH.$$

This reaction for palmitic acid may be represented as



(a)

In the formation of the saturated hydrocarbon, a further process is the return of the hydrogen atom from the unstable free carboxyl group to the alkyl chain,



(b)

or

$$C_{15}H_{32} + CO_2 \qquad \text{(c)}$$
n-pentadecane + carbon dioxide.

[8] Infra-red spectra of the liquid show absorption effects similar to those of mixtures containing 5 per cent palmitic acid.

The presence of carbon monoxide in the gaseous products indicates the free carboxyl group formed at stage (a) to be also sometimes disrupted by breaking of the bond between the carbon and the hydroxyl group. The latter group either combines with hydrogen to form water or returns (d) to the alkyl group, giving an alcohol and carbon monoxide.

$$CH_3(CH_2)_{14}OH + CO. \qquad (d)$$

Water is a product of the bombardment of palmitic acid (Table I) and its presence has been demonstrated in the gas produced from lauric acid. Alcohols have not yet been certainly identified in the residues of bombardments.

Dehydrogenation.—Hydrogen has been produced from all organic compounds that have so far been bombarded by alpha particles. The reaction of dehydrogenation of the fatty acids appears to be related to the length of the straight chain. The percentage of hydrogen formed (Table I) is about linearly proportional to the number of carbon atoms in the alkyl group.

Minor reactions.—In acetic acid methane is the product of decarboxylation, but small amounts of methane are also formed from the higher acids in the series. This methane is presumably eliminated from the straight chain by rupture of the carbon bond of the terminal methyl group.

The analyses (Table I) and the characteristics of the semi-liquid residues indicate the formation of other compounds in small quantities. These materials have not yet been studied.

Mechanism of reaction.—From the quantitative experiments, it appears that during a typical bombardment about one molecule of palmitic acid in fifteen within range of the alpha particles is converted to n-pentadecane. The energy of the alpha particles averages 100 electron volts[9] per molecule of acid converted, but it seems wholly improbable from theoretical calculations that such a quantity of energy is utilized in the reaction. Present interpretation is that all of the molecules of the fatty acid are affected by the alpha particles and are excited to states of high activity. Some decompose by decarboxylation, the preferred reaction, some lose hydrogen and some remain unchanged.

The chief difference between pyrolysis in the lower temperature range and reaction by alpha particles apparently is this high activation of the bombarded substance with production of hydrogen. At the temperatures of distillation (145° and 195°C. respectively), lauric and palmitic acids are stable. Decarboxylation, however, takes place in lauric acid at 270°C. and in palmitic acid at 295°C. (18) with formation of the corresponding ketone. No hydrogen is noted at these temperatures. At 600°C. pyrolysis of the fatty acids produces not only carbon dioxide but hydrogen, methane, and carbon monoxide. Activation of the acid molecules at such elevated temperatures may have some similarity to that caused by alpha particles.

[9] The electron volt is the unit of energy customarily used in nuclear physics, 1 e.v. $= 1.6 \times 10^{-12}$ erg.

SIGNIFICANCE IN PETROLEUM GENESIS

The role of radioactivity in the geochemistry of petroleum was first suggested by Lind. During the studies of the chemical action caused by alpha particles, he proposed (19) that, if geological conditions were met where alpha particles affected gaseous hydrocarbons, a liquid mixture of hydrocarbons similar to petroleum should be produced. Such a gaseous source material for petroleum is available in the large quantities of methane formed by bacterial decomposition in organic sediments. In the early part of the present project of research, described by Sheppard (8), consideration was given to this method of origin.

Recently Russell (20) and Beers and Goodman (21, 22) directed attention to the high content of radioactive elements in certain organic shales and confirmed earlier ideas (4, 23) that a likely process for the genesis of petroleum is the decomposition and conversion by alpha radiation of the solid and semi-solid organic constituents in marine sediments. Further testing of this hypothesis is now in progress. The research includes measurements of the radioactivity of sediments, determination of the radioactive content of fluids from oil fields,[10] and studies of the yields of significant reactions during bombardment by alpha particles. The objective is solution of the problem on a quantitative basis. The present contribution is a summary of that part of the work, as yet incomplete, on the fatty acids.

Source of fatty acids.—It has long been known that the oily material obtained from certain marine microscopic organisms contains fatty acids. Diatoms were collected on the Pacific Coast during the investigations by American Petroleum Institute Project 5, "Diatoms as a Source of Oil" (1, 24), and the oily lipid was extracted by petroleum ether. The extract (4.5 per cent of the dry weight) contained 35 per cent fatty acids (25). Analyses by Hashimoto (24) indicate them to be a mixture of higher, wax-like fatty acids (M.P. 90°C.) and lower unsaturated fatty acids.

Recently analyses were made by Clarke and Mazur (26) of the organic components in marine diatoms collected off Woods Hole or grown in pure culture. Free fatty acids constituted 60 to 80 per cent of the lipids extracted by ether, or 4 to 9 per cent of the dry weight of these diatoms. The mixture of free fatty acids from one sample analyzed in detail contained 81.7 per cent unsaturated and 18.3 per cent saturated acids. The latter included palmitic acid (60 per cent), stearic acid (36 per cent) and only minute proportions of lower and higher homologues. The results indicate that these diatoms contained about 1.6 per cent by dry weight of free saturated fatty acids. Fresh-water siliceous and marine calcareous sponges also gave oils with appreciable contents of fatty acids.

The lipids from the diatoms are also stated to show the presence of small amounts of hydrocarbons, in one case possibly hentriacontane. It is interesting to note that, after samples were allowed to stand six months alone or mixed in suspension with marine bottom mud, marked decrease in the fatty acid and some

[10] Measurements of the radioactivity of oil-field sediments and brines are being made under sponsorship of the Geological Society of America by grant from the Penrose Fund.

increase in hydrocarbon content were found. It is to be inferred that this hydrocarbon increase is caused by bacterial activity. ZoBell (27) has mentioned similar results by Russian workers. Apparently in the decarboxylation of fatty acids, alpha particles are to find competitors among the bacteria.

In the collection of the diatoms for analysis Clarke and Mazur placed some of the samples immediately under ether or acetone to prevent postmortem lipolysis which might have taken place in dried material. These samples also showed the bulk of the fatty acids to exist in the free state. Decomposition is believed not to be the cause of the presence of free acid in the extracts from these organisms.

According to ZoBell (27) such a source in decomposition by marine bacteria is to be expected where favorable conditions exist. He says that most lipolytic bacteria merely hydrolyze the fats and vegetable oils. The resulting glycerol is often oxidized as a source of energy while the fatty acids accumulate. Anaerobic or reducing environment favors the process. Quantitative data on fatty acids formed in this way in marine sediments are, however not available.

In fact, few analyses establish fatty acids in the free state as constituents of organic marine sediments. Trask states (28) in discussion of the work done by him and Wu (29) as part of American Petroleum Institute Project 4, that fatty acids normally occur in the samples rich in organic matter extracted with carbon tetrachloride. Information on their manner of occurrence was obtained for only one sediment (Sample No. 477). A free state of the acids was favored by this evidence. In the studies of diatoms by Clarke and Mazur (26), previously described, they analyzed also the organic material extracted by ether from marine bottom mud. Free fatty acids were identified.

The petroleum ether extract of the marine sediment analyzed by Wells and Erickson (30) was not studied in great detail. Oil-like acids and organic acids (9 parts per 100,000) were isolated. The fatty acids were extracted from another part of the sample by dilute alkali. The free fatty acids finally obtained by this method were believed possibly not all to have been in the sediment in the uncombined form. Different fractions of the fatty acids were separated and melting points determined. The range in melting points was similar to that of the saturated fatty acids, capric ($C_9H_{19}COOH$), lauric ($C_{11}H_{23}COOH$), myristic ($C_{13}H_{27}COOH$), palmitic ($C_{15}H_{31}COOH$), and stearic ($C_{17}H_{35}COOH$). Similarly from the melting points, Trask and Wu (29) tentatively identified caproic ($C_5H_{11}COOH$), cerotic ($C_{25}H_{51}COOH$), montanic ($C_{27}H_{55}COOH$), and melissic ($C_{29}H_{59}COOH$) acids. The last three are characteristically in the muds; the first was observed in the limestone-forming sediment from Florida Bay. The differences in the acids isolated by Trask and Wu and by Wells and Erickson may be explained in part by the different methods of analysis. Apparently saturated fatty acids over a considerable range in the series are nevertheless to be found in organic marine sediments.[11]

[11] Aliphatic acids from formic to valeric, with average molecular weight that of propionic acid, have been identified in water produced with condensate from the Katy field, Texas, and the South Jennings field, Louisiana, by Paul E. Menaul (*Oil and Gas Jour.*, Vol. 43, No. 27, November 11, 1944, pp. 80–81).

The quantities indicated by the few available analyses (Table V) are small. The average of the amounts determined in ether or carbon tetrachloride extracts is 6 parts per 100,000 of dry sediment. Other data by Trask (28, p. 178) show that about 0.2 per cent of the organic constituents in sediments from the Channel Islands, California, consists of fatty acids. In the sample from Chincoteague Bay, the fatty acids totalled 5 per cent of the organic matter. Such a range seems to be acceptable for normal marine bottom muds.

It is somewhat surprising that, in spite of the high content of fatty acids in diatoms, none of the investigations cited above has been directly concerned with marine diatomaceous sediments. Sedimentary deposits rich in diatoms are well known. Those described (31) from the Baltic Sea attain 8–10 per cent of organic material in the central depression east of Gotland. Trask (28, p. 237) states that

TABLE V
FATTY ACIDS IN MARINE SEDIMENTS

Author and Sample	*Parts per 100,000 Dry Weight*	*Percentage of Extract*
Trask and Wu (28, 29)		
Channel Islands, California No. 418	5	5.6
Florida Bay No. 454	2	3.7
Pamlico Sound No. 477	6	4.1
Wells and Erickson (30)		
Chincoteague Bay, Virginia	34[1]	12.6
	9[2]	21.9
Clarke and Mazur (26)		
Woods Hole	8	31.5

[1] Extracted with dilute alkali, NaOH, KOH.
[2] Extracted with petroleum ether.

the original organic content of the diatomaceous Monterey formation of California was at least 9 per cent. In the light of these facts, determinations of the fatty acids in some recent sediments of this kind are needed before final decision is made on the significance of the saturated fatty acids in the origin of petroleum.

Rate of conversion.—A method for estimating the rate of transformation of organic materials by alpha radiation in a uniform, fine-grained sediment has been given (8) by Sheppard. His equation includes the ratio ($\Delta M/\Delta N$) of the number of molecules of the organic substance transformed by the radiation to the number of ion pairs produced in the sediment. In the present discussion it is convenient to use instead the number (M_p) of molecules of product per electron volt expended in the material and to express the relation in a slightly different form

$$\frac{dM}{dt} = M_p\, C(5.5 \times 10^{11}\ U + 1.5 \times 10^{11}\ Th)$$

where C, U, and Th are the mass concentrations in the water-containing sediment of organic material, uranium, and thorium, respectively, and dM/dt is the number of molecules converted per second per gram of sediment.

In the conversion of palmitic acid, the highest yield was 0.018 molecule of n-pentadecane per electron volt. This value for Mp will be considered applicable to the other free saturated fatty acids in the hypothetical sediment for which the rate is to be calculated.

Maximum values also will be used for C, U, and Th, corresponding with those determined on dry Antrim shale by Beers and Goodman (21) and further discussed by Beers (22). The shale is supposed to have contained 55 per cent water by volume (33 by weight) and its organic material to have carried 5 per cent free saturated fatty acids.

Under these assumptions

$$\frac{dM}{dt} = 0.018 \times 0.66 \times 0.16 \times 0.05(5.5 \times 10^{11} \times 28 \times 10^{-6} + 1.5 \times 10^{11} \times 273 \times 10^{-6})$$

$$= 9.6 \times 10^{-5}(154 \times 10^{5} + 409 \times 10^{5})$$

$= 5{,}400$ molecules of paraffine hydrocarbons per second per gram of sediment.

By assuming further that the hydrocarbons have a mean molecular weight of 250, it is found that $6.8^{\times 10^{-4}}$ gram of hydrocarbons per gram of sediment would be produced in 10 million years.

The Antrim shale in the Pure Oil Company's Gingrich No. 3, Osceola County, Michigan, is 207 feet thick. In a compacted shale of this thickness, the foregoing yield in 10 million years would amount to about 208 barrels of oil per acre foot of sediment. This quantity, considering the maximum values used for organic matter and radioactivity, is not large.

It happens that the yield calculated in this way for the Antrim shale is close to that necessary to supply the oil in the Santa Fe Springs field, California. Trask (32) found that 5.3×10^{-4} gram of oil per gram of sediment in the volume of possible source beds would account for the initial oil content of the field. In spite of this coincidence, the calculations are not comparable. The Antrim shale is rich in organic material and is exceptionally high in radioactivity. A computation, similar to the preceding, for the Santa Fe Springs field would probably give much lower quantities of oil from fatty acids converted to hydrocarbons by alpha particles. Data are lacking for the calculation, but it appears that not more than one per cent of the oil in the field could be accounted for by radioactive transformation of fatty acids.

The results of the computation should be accepted with considerable reserve, since some of the factors involved in the analysis are uncertain. In the example discussed here, a hypothetical sediment from which the Antrim samples might have been produced, several assumptions are made. Uniformity of distribution of

radioactive elements and of organic constituents is presumed. Original fatty acid content is entirely conjectural. Much further detailed information is needed on yields from alpha-particle reactions and on the organic components and radioactivity of sediments to make any quantitative treatment of the rate of conversion truly satisfactory.

CONCLUSION

The experiments performed in this research appear to show beyond reasonable doubt that, during bombardment by alpha particles, saturated fatty acids are converted to paraffine hydrocarbons. The decarboxylation induced results in the hydrocarbon corresponding with the long chain of the fatty acid. Appropriate fatty acids, from acetic acid to higher members of the series, may produce by this process methane or other paraffine hydrocarbons found in petroleum. Carbon dioxide, the gaseous product of the reaction, is a common constituent of terrestrial gases.

Minor reactions give small amounts of methane and carbon monoxide. The latter may in part be caused by reconversion of carbon dioxide. Further studies of the formation of this gas are in progress.

Dehydrogenation always takes place and hydrogen from the effects of alpha particles increases with the length of the long chain of the bombarded molecule. Hydrogen is apparently a rare gas in oil fields. Its production during the bombardment of organic substances remains an unsolved problem in the research.

Certain of the fatty acids have been identified in the organic material of marine sediments. Both saturated and unsaturated fatty acids are present in surprising quantities in the ether extract from diatoms and other organisms. On the basis of these facts, it is inferred that the energy from radioactive disintegration is effective from this source in the formation of some of the hydrocarbons found in petroleum.

The efficiency of utilization of energy in the process is low. But one molecule of hydrocarbon is produced by 56 electron volts expended by the alpha particles in the substance. The rate of conversion is, therefore, small; but calculations indicate it to be not negligible under geological conditions.

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STRATIGRAPHY OF WALLER AND HARRIS COUNTIES, TEXAS[1]

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ABSTRACT

The writer discusses the stratigraphy of Waller and Harris counties, Texas, a total thickness of 11,004 feet of Gulf Coastal Plain formations. He describes their lithologic characteristics and faunal markers, ranging from the Lissie formation (Pleistocene) into the Wilcox (Eocene). An attempt is made to give an accurate description of the formations penetrated, by a study of logs, electrical surveys, well cores, and cuttings. The composite stratigraphic section necessarily shows fixed intervals, but it is not the intention of the writer to give the impression that they remain constant for that is not true; they vary both updip and downdip.

INTRODUCTION

It has long been the opinion of the writer that a paper describing the stratigraphy of the Gulf Coast in sequence from the surface to and including the Wilcox would be of some value. To cover such a wide scope would entail much research and would require unlimited time. In this paper the stratigraphy of only Waller and Harris counties, Texas, is described. The total thickness of this stratigraphic section is 11,004 feet, ranging from the Lissie (Pleistocene) to the Wilcox (Eocene).

Although known to be present in a part of the two counties, the Beaumont clays are not considered; this description begins with a discussion of the Lissie.

LISSIE

Exposures in southeastern Waller and northern Harris counties are recognized as being primarily the Lissie formation, Pleistocene in age, composed of loose deposits of light tan-colored sands and sandy clays. Deussen[3] originally described the Lissie in Wharton County as a series of sands and gravels underlying the Beaumont clays and overlying the Fleming clays. He mapped the outcrop, and it is presently outlined as a broad belt of sandy soils between the outcrops of the two clayey formations.[4]

Although shown underlying the Beaumont clays and overlying the Fleming clays, actually the Lissie rests unconformably on the Willis—a formation of post-Fleming age described by Doering.[5]

[1] Manuscript received, October 10, 1945.

[2] Independent consultant. The writer gratefully acknowledges the courteous assistance of M. C. Israelsky, chief paleontologist of the Union Producing Company, in examining samples from the Lissie into the Catahoula. He also extends his thanks to those companies which made material available, and which are cited in this paper.

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Geologic Map of Texas, U. S. Geol. Survey (1937).

[5] John Doering, "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935), p. 668.

Doering estimated that the Lissie thickens at the rate of 15 feet per mile coastward from its outcrop.[6] This together with the fact that samples from the Stanolind Oil and Gas Company's Thorp well No. 1, J. M. Bennett Survey, Sec. 100, Abstract 280, southern Waller County, showed sand with some fine gravel to 300 feet, leads to the assumption that the Lissie is a mantle approximately 300 feet thick over southern Waller County and northern Harris County. Intervals and depths used throughout conform to the composite stratigraphic section, Fig. 1, and both vary according to the area selected.

From the surface to 80 feet, the mantle is fine- to medium-grained yellow sand with abundant orange-colored grains, gradually becoming coarser. At 200 feet, fine gravel with disseminated sand is encountered. Orange-colored sand grains are still plentiful and the lithologic character continues uniform to the depth of 300 feet, which is apparently the base or near the base of the Lissie.

Electrical surveys of the Humble Oil and Refining Company's E. C. Stockdick No. 2, H. & T. C. R.R. Co. Survey, Sec. No. 113, Abstract 173, Waller County, and of water wells drilled in the counties show sands of low self-potential and high resistivity, indicating that the Lissie sands are a potential source of fresh water. Water from these sands is used by rice farmers for irrigating and by oil companies for drilling operations.

WILLIS

Willis is the name Doering[7] proposed for the Pliocene formation underlying the Lissie unconformably and described by him as the sand and gravelly sand at or near the base of the post-Fleming group in southeast Texas and south Louisiana.

In the same publication, he further describes the Willis as consisting of three members which in ascending order are: Willis gravelly sand, Willis ferruginous sand, and the Hockley Mound sand. He assigns the maximum thickness of 125 feet to the group at their outcrop.

The name Willis was derived from the town of Willis, northern Montgomery County, Texas, where the lower members are exposed. It is also exposed in northeastern Waller County and northwestern Harris County. It dips under and disappears beneath the Lissie. Examination of samples from the Stanolind Oil and Gas Company's Thorp No. 1 revealed a subsurface section from 300 to 400 feet feet composed of sand and coarse gravels. The sand is coarse with abundant orange-colored grains and the gravel ranges from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter. The lower 15 to 20 feet contains small amounts of pink, calcareous clay with calcareous nodules. The coarse gravel constituent increases toward the base. This zone seems to be the subsurface equivalent of Doering's surface Willis and the Willis exposed in Waller and Harris counties. It differs primarily from the Lissie

[6] *Ibid.*, p. 669.

[7] John Doering, *op. cit.*, pp. 660–68.

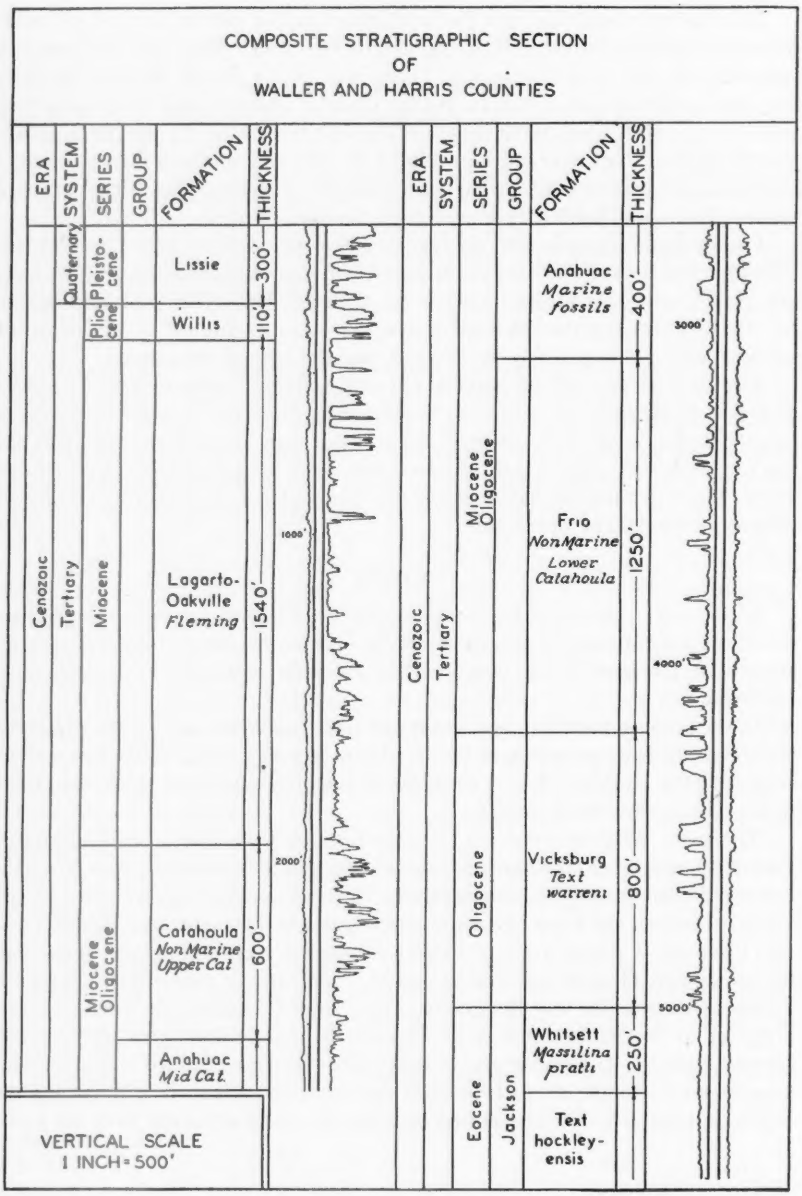

FIG. 1.—Composite stratigraphic section of Waller and Harris counties, Texas.

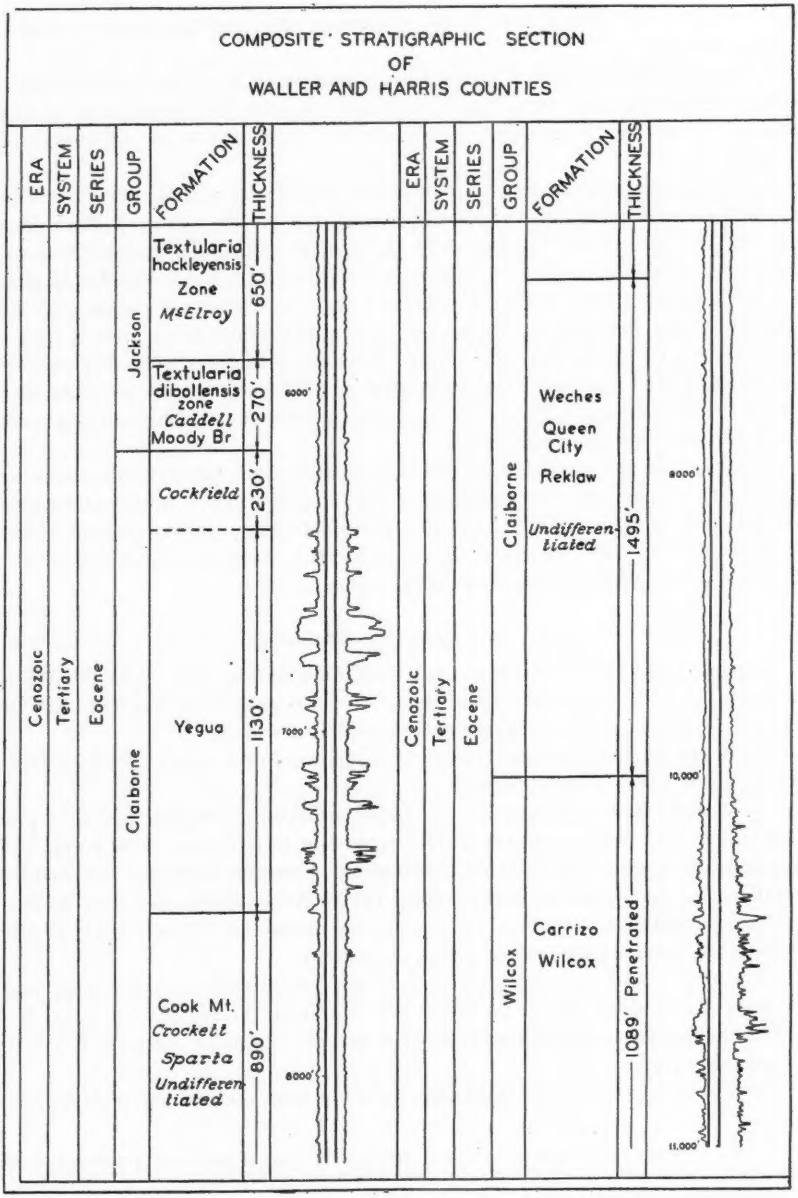

Fig. 2.—Composite stratigraphic section of Waller and Harris counties, Texas.

in the coarseness of the gravel, in the calcareous clay, and the presence of calcareous nodules.

Unfortunately, as few well samples have been saved near the surface and few electrical surveys have been made at shallow depths, the segregation of the younger formations is exceedingly difficult and there are many differences of opinion.

After considerable search, it was found that the Layne-Texas Company made electrical surveys of water wells in southern Waller and northern Harris counties. By using these together with the surveys of oil wells and dry holes, a composite picture was obtained (Fig. 1). A typical water-well survey is the Layne-Texas Company's Rice Milling Company 1-B, in the northeast corner of J. R. Garrett Survey, Sec. No. 68, Abstract 1395, Waller County. Since there is apparently very little dip in the near-surface Pleistocene-Pliocene beds, this survey can be correlated readily with the electrical and lithologic logs of the Stanolind Oil and Gas Company's Thorp No. 1, and others where obtainable. Their similarity is easily seen upon comparison.

It is recalled that the lithologic description showed the Lissie-Willis extending to a depth of 400 feet. The electrical survey indicates heavy fresh-water sands extending to 410 feet (Fig. 1) where a prominent clay "break" begins, this is comparable with that determined by lithology. It is, however, impossible to separate the Lissie-Willis by use of electrical surveys.

LAGARTO-OAKVILLE (FLEMING)

Lagarto-Oakville is the name used for the formation underlying the Willis and overlying the Catahoula. It is used as the prototype of the Lagarto-Oakville (Miocene age) of southwest Texas and as used by Doering.[8]

H. V. Howe has discussed the section, giving a bibliography with excerpts from various authors, in his paper.[9]

In Waller and Harris counties, the Lagarto-Oakville is represented by a predominantly clay section approximately 1,550 feet in thickness or to a depth of approximately 1,950 feet. Within this interval, however, there are interbedded sand bodies that range in texture from friable fine-grained, to coarse-grained gravelly sandstones, some of which are slightly calcareous. The sands are mostly yellow, but some orange-colored grains are present.

The clays, pink and pale green in color, are calcareous, containing lime nodules. Reworked Cretaceous fossils are abundant throughout the zone, but fossils indigenous to it are scarce. *Rotalia beccarii*, the most common, has little diagnostic value.

Electrical logs show the sand bodies have low self-potential and high resistiv-

[8] John Doering, "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," *Gulf Coast Oil Fields*, Amer. Assoc. Petrol. Geol. (1936), p. 439.

[9] H. V. Howe, "Review of Tertiary Stratigraphy of Louisiana," *ibid.*, pp. 413–17.

ity, and the clays have the usual characteristics. Drillers commonly log the section as shale and sand, or sandy shale and sand with hard sticky streaks.

In southwest Texas, the Oakville sand occurring at or near the base of the formation is easily recognized, but it is not so differentiated in the central Gulf Coast.

CATAHOULA

The Catahoula as used in this discussion is intended to include the section underlying unconformably the Lagarto-Oakville previously described and overlying the Anahuac formation. It includes, in part, Bailey's Gueydan.[10] The age of the Catahoula is a moot question. It has been variously described as Miocene or Oligocene in age, or both.

This formation, extending from approximately 1,950 feet to 2,550 feet, is composed of pink and green calcareous shales with intermittent sand bodies. Salt-and-pepper sands together with volcanic glass and rare *Discorbis* are the criteria commonly used in determining the top of this formation. Some gypsum has also been found in lithologic descriptions of well samples. Drillers log the section as shales, sandy shales, sticky shales, sand and shales with an occasional descriptive color. Electrical surveys record essentially a sandy shale section with sands prevailing near the top.

ANAHUAC (MIDDLE CATAHOULA)

The Anuahuac formation of Ellisor,[11] or the Anahuac wedge of Eby,[12] is represented by a thinning updip phase of marine sediments. It covers an interval of 400 feet from 2,550 feet to 2,950 feet and is recognized by the presence of marine fossils. The zone is frequently referred to as the middle Marine zone or the middle marine Oligocene. The Anahuac is not typically developed in southern Waller or northern Harris counties. In this updip phase, the fauna is somewhat limited: *Ostrea* shell fragments, *Bryozoa*, *Elphidium*, and rare *Heterostegina* are most commonly present. All of these and others are found in the downdip phase where the interval thickens.

The shales are greenish in color and interbedded with sand bodies. The sands are calcareous, micaceous, and intercalated with shale. Electrical logs show the zone as having characteristic features, making it easily recognizable and suitable for correlative purposes.

FRIO (LOWER CATAHOULA)

The formation from 2,950 feet to approximately 4,200 feet has been desig-

[10] Thomas L. Bailey, "The Gueydan, a New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Univ. Texas Bull. 2645* (1926), pp. 62–105.

[11] Alva C. Ellisor, "Anahuac Formation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 28, No. 9 (September, 1944), pp. 1355–68.

[12] J. Brian Eby, "Oil and Gas Fields of Jackson County, Texas," *Oil Weekly* (September 27, 1943), pp. 20–26.

nated Frio, even though the term is not universally accepted, and a debate arises when one asks, "What is the Frio?" Herein the intent is to include the section underlying the Anahuac and overlying the Vicksburg unconformably. In Gulf Coast terminology, it is often referred to as non-marine Oligocene, the paucity and brackish nature of the fossils within the zone being the basis for this. The section is comprised chiefly of sticky, calcareous, blue and green clays and shales. Some lime shells, lime nodules, and bentonite may be found upon close lithologic examination of well samples. Drillers log the Frio (lower Catahoula) as sticky shales, and sandy shales with lime shells and here and there sands.

Electrical surveys of Waller and northern Harris counties depict a shale section with some sandy phases. Near the base, sand bodies become somewhat more numerous. Cores are rarely taken in this interval, and those taken have invariably been of sands containing water. In southern Harris County, the Frio sands are well developed, and at Clear Lake, Webster, and other fields in Harris County they are highly productive, and are oil reservoirs of major importance. Electrical surveys of the Frio (lower Catahoula) in this area are characteristically different from those farther north.

VICKSBURG (OLIGOCENE)

Underlying the Frio (lower Catahoula) is the Vicksburg—first recognized by Ellisor in Texas in 1927.[13] In Waller and Harris counties, it is well developed having a thickness of 750 feet plus or minus. The top is usually recognized where the blue and green shales and sands of the Frio (lower Catahoula) end, and the brown lignitic shales begin. In the Amerada Petroleum Company-Stanolind Oil and Gas Company's Manor No. 1, H. & T. C. R.R. Co. Survey, Sec. 93, Abstract 164, Waller County, this contact was first noted by the Union Producing Company at 4,290 feet, and was found somewhat higher in the Stanolind Oil and Gas Company's Thorp No. 1, farther south.

Near the top of the Vicksburg, the fauna is sparse. Within the zone from 350 to 400 feet, *Textularia warreni* is found, with the associated suite of fossils becoming more profuse and in places abundant. Commonly, the Foraminifera are found in shale at or near the base of a heavy sand. Locally, *Textularia warreni* can be used for correlating, but regionally it is a poor marker as its occurrence within the formation is erratic.

The interval is logged as brown mudstone, sticky shale, sands and limy sand. Electrical surveys show a definite pattern, with the sands better developed in the upper part, and the lower part predominantly shale with the sand appearing near the base just above the Whitsett.

JACKSON (EOCENE)

The Jackson as described herein is intended to include the 1,200 feet of section

[13] Alva C. Ellisor, "Jackson Group of Formations in Texas with Notes on Frio and Vicksburg," *Gulf Coast Oil Fields*, pp. 498–501.

between the depths of 5,000 feet and 6,200 feet, that which underlies the Vicksburg and overlies the Yegua (Cockfield). Paleontologically, its top is recognized by the presence of *Discorbis jacksonensis*, *Uvigerina cocoaensis*, and an associated suite of Foraminifera. The base is 20 to 30 feet below a marly phase that contains the diagnostic *Operculina vaughani*, *Camerina moodybranchensis* and *Camerina jacksonensis*, with their associates. This basal member is often referred to as the Moody Branch and forms an excellent marker.

Three well defined zones are now recognized in the Jackson: the Whitsett, the *Textularia hockleyensis* or McElroy, and the *Textularia dibollensis* or Caddell.

The Whitsett is the uppermost, has an average thickness of 250 feet, and extends through the *Massilina pratti* to the top of the *Textularia hockleyensis*. Drillers log this section as shale and sticky shale; their interpretation is borne out by the uniform shale pattern exhibited on electrical surveys. The Foraminifera *Massilina pratti* is a reliable marker in the Whitsett that is used by geologists and sought by paleontologists.

The middle or *Textularia hockleyensis* zone (McElroy) covers an interval of 650 feet. Its top is determined by the occurrence of the *Textularia hockleyensis*, one of the better Foraminifera markers found on the Gulf Coast. Lithologically, and by electrical surveys, there is little variation between the Whitsett and the *Textularia hockleyensis* zones. The same shale pattern of the electrical surveys continues and the same description applies to the penetrated formation.

The lower 270 feet of the Jackson has been described as the *Textularia dibollensis* zone or Caddell. Though varying, its top is recognized by the occurrence of *Textularia dibollensis* with associated fauna or by the appearance of green glauconitic shales. Shales continue nearly to the base where a marly member (Moody Branch) appears, containing the Foraminifera previously mentioned. Electrical surveys show a definite pattern for the *Operculina-Camerina* (Moody Branch), commonly known as the "Operc. kick."

YEGUA (CLAIBORNE-EOCENE)

The Yegua as used here for the formation between the overlying Jackson and the underlying Cook Mountain (Crockett). It occurs between 6,150 feet and 7,500 feet, and has a thickness of 1,350 feet.

Considerable confusion in the nomenclature of the "Yegua" has existed. A résumé of Yegua nomenclature has been fully prepared by F. B. Plummer,[14] and an excellent paper by H. B. Stenzel[15] has been published.

In the stratigraphic section (Fig. 1), the top of the Yegua has been placed approximately 30 feet below the Moody Branch at which point the diagnostic Foraminifera, *Nonionella cockfieldensis*, ordinarily appears. Here also, is a marked lithologic change. The shales of the preceding formation are green and glauconitic, but the top shales of the Yegua are brown and lignitic.

[14] F. B. Plummer, "Cenozoic Systems in Texas," *Univ. Texas Bull. 3232* (1932), pp. 666–68.

[15] H. B. Stenzel, "The Yegua Problem," *Univ. Texas Bull. 3945*, pp. 847–904.

The upper 250 feet of the Yegua is commonly referred to as the Cockfield. It is within this zone, near the top, that the upper Cockfield sand, Pettus of southwest Texas, is located, but its distribution is not continuous. In the northern part of the Katy field, Waller County, the sand is present and gas-bearing, but in the southern part it is absent. Likewise, in the Fairbanks-Rosslyn-North Houston field, Harris County, the sand is found in a few of the wells but in most of them it is entirely missing. Where present and cored, the sand is medium- to fine-grained; however, it has not been consistently cored as production is usually sought below this horizon.

Below the Cockfield is found a series of blanket sands and shales having a thickness of 1,130 feet. Although present and productive elsewhere, since these sands are well developed in the Katy field, Waller County, and as information pertaining to them is readily available, they are used for descriptive purposes and the same zonation as that of the field retained. There are five of these zone based on production and each of these is composed of from one to three sand members with separating shale bodies.

Lithologically, the sand, by zones, may be described as follows.

First zone—Hard to soft, gray sandstone ranging from medium- to fine-grained with some siltstone lamination

Second zone—Firm, fine-grained gray sands. Parts are slightly calcareous, interbedded with brown shale

Third zone—Firm, medium- to fine-grained sands interbedded in thin streaks with lignite. Marked tendency toward tightness with separation by shale "breaks"

Fourth zone—Sand ranges from hard, fine-grained, tight sand with laminae of lignite to firm, clean, gray sand with here and there a thin bed that is hard, tight and quartzitic

Fifth zone—Coarse, angular, hard, and pyritized or medium- to fine-grained, angular grey sands. Some beds dense and lignitic

The total combined thickness of the sands (exclusive of the Cockfield) is nearly 250 feet. From well to well, there are local variations in core descriptions due as much to the personal element in description as to actual physical differences.

The remaining 880 feet of the 1,130 foot section is made up of shales and sandy shales. These, from cores, are described as brown and black ring-tail shales, tight lignitic sandy shales, sticky fossiliferous shales, gray lignitic shales, hard micaceous shales, and gray sandy shales.

Drillers log this interval as shales, hard sandy shales, sticky shales and sands, recognizing the major sand bodies with fair accuracy. Electrical surveys show well developed sand bodies with a consistent pattern.

Microfauna are fairly abundant throughout the Yegua, but once *Eponides yeguaensis* is recognized, and it occurs 250 feet plus or minus below *Nonionella cockfieldensis*, little attention is paid to the ensuing Foraminifera.

COOK MOUNTAIN (CLAIBORNE-EOCENE)

The next succeeding formation in the Claiborne series is the Cook Mountain (Crockett), the top of which is determined paleontologically by the occurrence of

the Foraminifera *Ceratobulimina eximia.* The fossil is commoly found in the shale 50 to 75 feet below the base of the last Yegua sand or the true top. In the Stanolind Oil and Gas Company's Thorp No. 1, this faunal marker was found at 7476 feet; in the Stanolind's Freeman No. 1, a southwest offset, at 7,602 feet; and in the Texas Gulf Producing Company's Weary No. 1, E. Farias Survey, Aldine area, Harris County, at 7,640 feet.

In the published records describing surface occurrences, the Cook Mountain is generally used to designate only those beds above the Sparta sand (first described by Vaughan[16]) and below the Yegua.[17] As the Sparta sand or its equivalent is not generally recognizable from electrical surveys or well cuttings in this area the two formations have been left undifferentiated. Nine hundred feet, more or less, is the combined thickness of the two.

WECHES

Wendlandt and Knebel[18] described the surface exposures and proposed the name Weches for the middle glauconitic bed between the Sparta and Queen City sands. This nomenclature has been almost universally adopted. Where the Weches is encountered at considerable depth, as in Waller and Harris counties, the overlying Sparta sand is absent, having "shaled out"; therefore, the top of the Weches, like the Cook Mountain, is determined by use of faunal markers. Those in common use are *Textularia smithvillensis, Lamarkina claibornensis,* and *Discocyclina advena.*

Below the Weches, the Queen City sand, which is present on the surface, has disappeared and is not differentiated. Its equivalent is represented by a shale section, which continues to the top of the Wilcox, the lower part presumably being Reklaw. Lower Claiborne fauna below the Weches are fairly abundant, but so far reliable diagnostic Foraminifera have not been isolated.

The only well in Waller County to have penetrated these lower Claiborne formations is the Stanolind's Freeman No. 1, H. & T. C. R.R. Co. Survey, Sec. 99, Abstract 167. This well shows an over-all thickness, from the top of the Weches to the top of the Wilcox, of 1,500 feet.

Drillers have logged the entire section from the top of the Cook Mountain to the Wilcox as being predominantly shale. An examination of well cuttings reveals gray and brown fissile claystones with a few thin sandy streaks. The electrical survey is corroborative—the latter being remarkable in its uniformity unmarred by sand "breaks."

[16] Vaughan, "Texas in Its Geognostic and Agricultural Aspect," *Amer. Nat.*, Vol. 13 (1879), pp. 375–84.

[17] H. V. Howe, "Review of Tertiary Stratigraphy of Louisiana," *Gulf Coast Oil Fields*, p. 394. F. B. Plummer, "Cenozoic Systems in Texas," *Univ. Texas Bull. 3232* (1932), pp. 655–57.

[18] E. A. Wendlandt and G. M. Knebel, "Lower Claiborne of East Texas with Special Reference to Mount Sylvan Dome and Salt Movements," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 10 (October, 1929), p. 1356.

WILCOX (EOCENE)

Although this division had been recognized by other geologists for some time the name Wilcox was given the group by Crider[19] in 1906. Since there has been some controversy about the Carrizo belonging to the Claiborne group or to the Wilcox group, the Carrizo is here incorporated with the Wilcox and thought of as Carrizo-Wilcox for simplicity.

In 1937, the Superior Oil Company of California drilled its Butler No. 1, James Ehrhardt Survey, Bammel area, Harris County, to the total depth of 10,574 feet. This was the first well drilled so far coastward reaching the Wilcox, which it did at 9,720 feet plus or minus. Considerable interest was created and a new goal set for future drilling operations.

In Waller County, the only well to have reached the Carrizo-Wilcox is the Stanolind's Freeman No. 1. The formation was found in this well at 9,915 feet, and was still present at 11,004 feet, a thickness of 1,089 feet having been penetrated.

A few other wells in Harris County have gone to the Carrizo-Wilcox but without producing oil.

The group is made up of a series of alternating sands and shales which have been extensively cored in the Stanolind's Freeman No. 1. From core description, the Wilcox is composed of hard to very hard, micaceous shale, sandy shales, and sandstones with laminae of lignite. The sands are very tight, apparently having low porosity and permeability. At 10,600 feet, very hard tight glauconitic fossiliferous sand was cored, which was the only one recorded in the cores from this well.

Drillers logged the section as hard sands and shales, while the electrical survey shows a series of sales and sandy shales with a few well developed sand bodies of low self-potential.

The electrical survey has the usual Wilcox pattern with the top easily recognizable. A definite break is discernible where the overlying Claiborne series ends and the Carrizo-Wilcox begins.

[19] A. F. Crider, "Geology and Mineral Resources of Mississippi," *U. S. Geol. Survey Bull. 283* (1906), pp. 25–28.

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VOL. 30, NO. 1 (JANUARY, 1946), PP. 63-83, 2 FIGS.

MINERALOGY OF LATE UPPER CRETACEOUS, PALEOCENE, AND EOCENE SANDSTONES OF LOS BANOS DISTRICT, WEST BORDER OF SAN JOAQUIN VALLEY, CALIFORNIA[1]

S. N. DAVIESS[2]
Los Angeles, California

ABSTRACT

The mineral composition of 192 outcrop and core samples from sandstones of late Upper Cretaceous, Paleocene, and Eocene age in the Los Banos district are tabulated. The mineral composition appears to afford few data for differentiating and correlating late Upper Cretaceous and Paleocene sandstones of the Los Banos district. The Eocene Domengine formation in the southern part of the area shows a marked increase in glaucophane as compared with the Paleocene and late Upper Cretaceous sandstones. The mineral suites are interpreted as indicating derivation from eastern and western sources, glaucophane being the most reliable indicator of a western source. Kaolinite, possibly of the anauxite type, occurs in white sands of Ione type in the Martinez (?) formation of possible Paleocene age, in outcrop sections and in a subsurface sand.

INTRODUCTION

The stratigraphy of late Upper Cretaceous, Paleocene, and Eocene formations exposed in the foothills of the Coast Ranges in the Los Banos district, located in the northwestern part of the San Joaquin Valley, was recently described by Stewart, Popenoe, and Snavely[3] in Preliminary Chart 6 of the Geological Survey's Oil and Gas Investigations series.

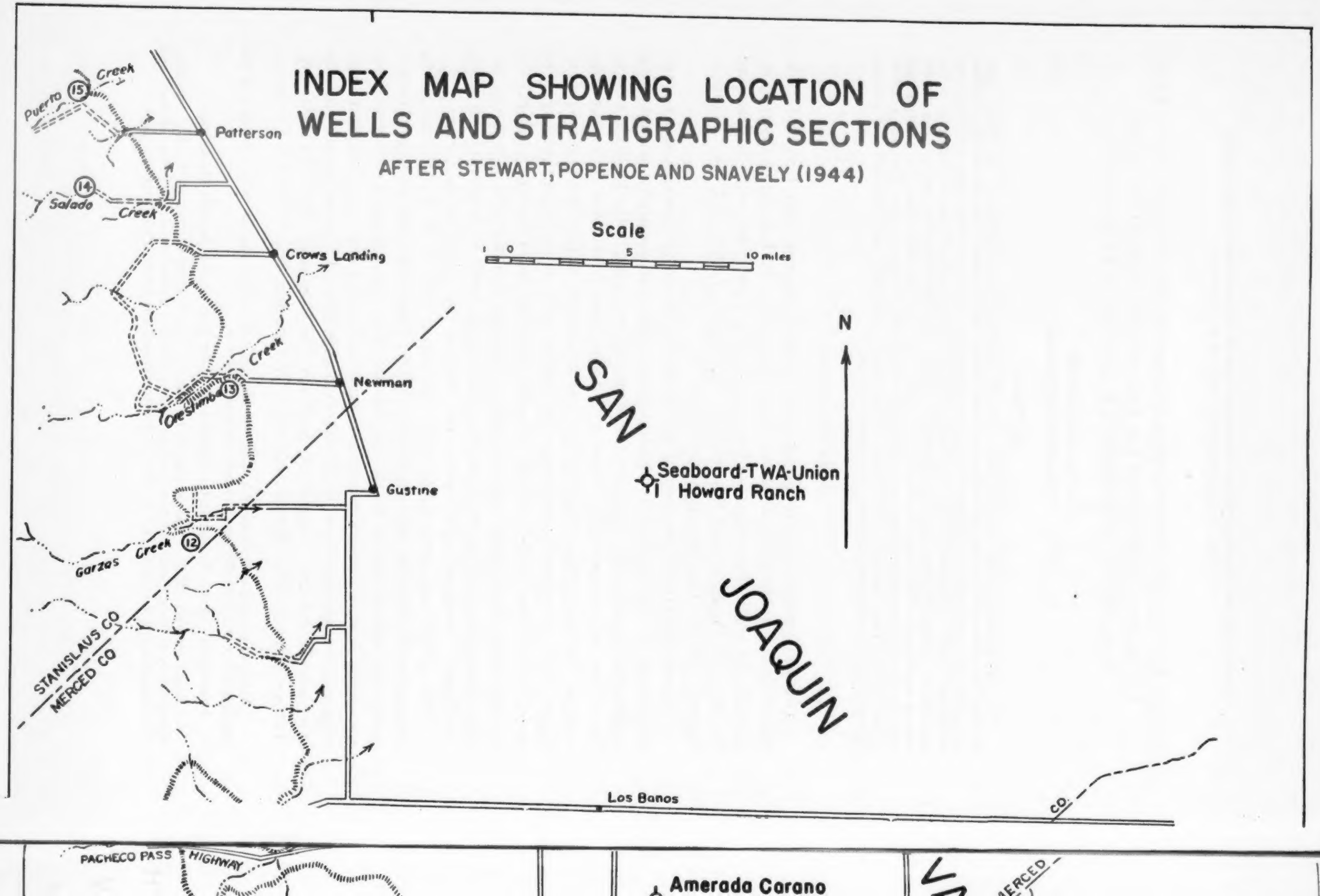
This study of the mineralogy of late Upper Cretaceous, Paleocene, and Eocene sandstones of that district was undertaken to test the possibility of obtaining additional data for differentiating the formations exposed in the foothills west of the valley and of correlating them with formations penetrated by exploratory wells on the valley floor. Correlation of the subsurface section below the Kreyenhagen shale is uncertain, owing to the meager microfaunas and the scarcity of megafossils. It was hoped that the mineralogy of the Upper Cretaceous might aid in correlating the exposed strata south of Pacheco Pass with those north of the pass. According to Stewart, Popenoe, and Snavely, fossil evidence for correlating the Upper Cretaceous strata north and south of the pass is inconclusive.

The project was undertaken under the supervision of W. P. Woodring. The mineral-grain samples were studied by M. N. Bramlette, and by S. N. Daviess under the supervision of M. N. Bramlette. The data and the paper were reviewed by A. O. Woodford, whose assistance and criticism are gratefully acknowledged. Core material from wells was available through the cooperation of the Amerada Petroleum Corporation, Seaboard Oil Company, Shell Oil Company, Texas Company, Tide Water Associated Oil Company and Union Oil Company.

[1] Manuscript received, October 4, 1945. Published with the permission of the director of the Geological Survey, United States Department of the Interior.

[2] Geological Survey, United States Department of the Interior, Los Angeles, California.

[3] Ralph Stewart, W. P. Popenoe, and P. D. Snavely, Jr., "Tertiary and Late Upper Cretaceous Stratigraphy of West Border of San Joaquin Valley, North of Panoche Creek, Fresno, Merced and Stanislaus Counties, California," *U. S. Geol. Survey Oil and Gas Invest. Prel. Chart 6* (1944).


INDEX MAP SHOWING LOCATION OF
WELLS AND STRATIGRAPHIC SECTIONS
AFTER STEWART, POPENOE AND SNAVELY (1944)
Scale
0
5
10 miles
N
SAN
JOAQUIN
Seaboard-TWA-Union
1 Howard Ranch
Puerto
Creek
15
Patterson
14
Salado
Creek
Crows Landing
Creek
Newman
13
Orestimba
Gustine
Garzas
Creek
12
STANISLAUS CO
MERCED CO
Los Banos
CO.
PACHECO PASS
HIGHWAY
Amerada Carano

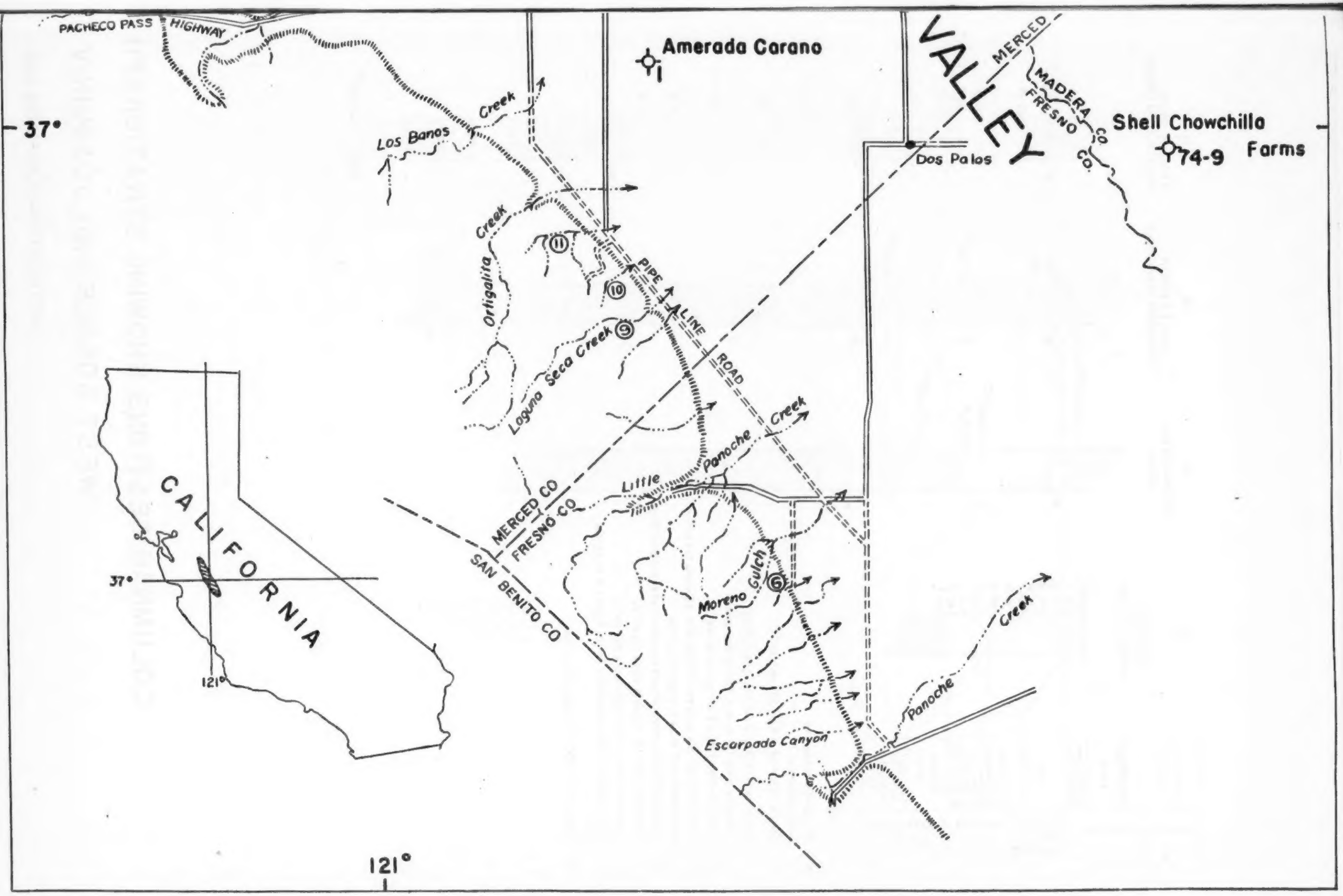


FIG. 1.—Index map showing location of wells and stratigraphic sections.

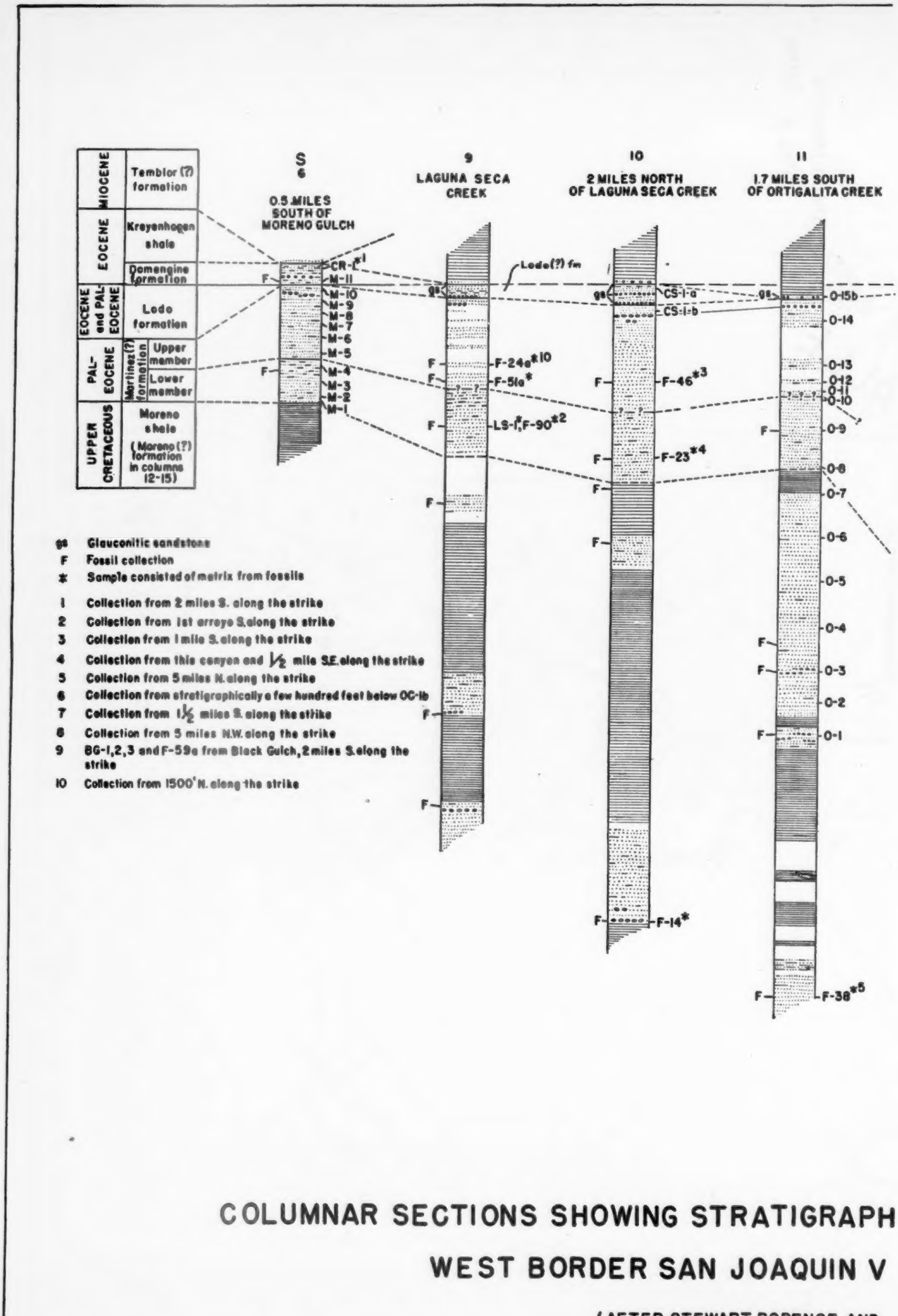
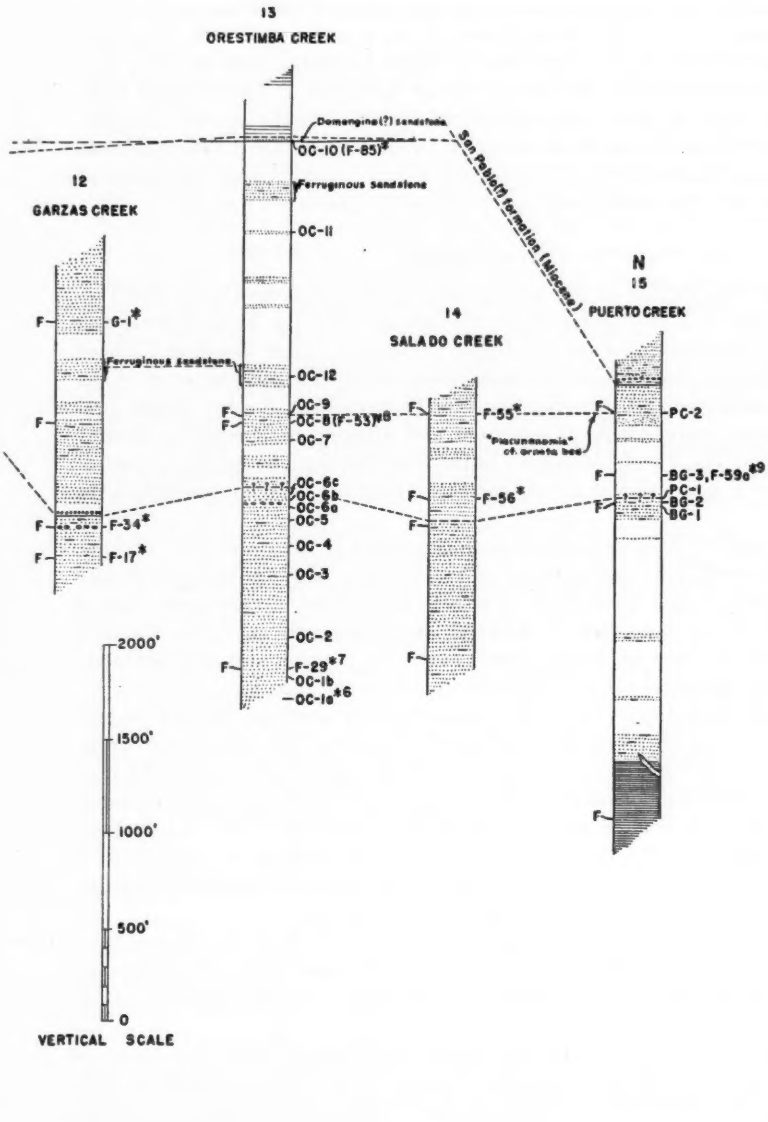


FIG. 2.—Columnar sections showing stratigraphic position of



IC POSITION OF OUTCROP SAMPLES,

ALLEY, CALIFORNIA

SNAVELY, 1944)

outcrop samples, west border San Joaquin Valley, California.

P. P. Goudkoff kindly furnished data on the correlation of the subsurface section.

The location of the wells, which furnished the core samples, and of the outcrop sections that were sampled is shown in Figure 1, adapted from the index map of the Geological Survey's Preliminary Chart 6. Figure 2, also adapted from Preliminary Chart 6, shows the stratigraphic position of the outcrop samples. In both illustrations the numbers for the columnar sections are the same as those of Preliminary Chart 6. Owing to the scale of Figure 2, the lithology is generalized as compared with the corresponding columns of Preliminary Chart 6.

STRATIGRAPHY

The following outline of the stratigraphy is adapted from the text of Preliminary Chart 6. The oldest samples studied are from the Moreno shale and Moreno (?) formation, and are late Upper Cretaceous in age. South of Pacheco Pass, the Moreno shale consists of dark brown shale, white diatomaceous shale, and some sandstone and siltstone. North of Pacheco Pass, the late Upper Cretaceous strata consist chiefly of sandstone and siltstone, designated the Moreno (?) formation. The *Turritella chaneyi* fauna from the fossiliferous upper part of the Moreno (?) along Garzas Creek (column 12) has not been found south of the pass.

The Paleocene Martinez (?) formation consists of sandstone and siltstone, with minor amounts of conglomerate and ferruginous sandstone. The contact with the underlying Upper Cretaceous is locally marked by conglomerate, but is gradational throughout much of the area. In the southern part, the Martinez (?) is divided into two members, a lower more silty member and an upper sandy member. The members are not recognized north of Pacheco Pass.

The Lodo formation is definitely recognized only south of the area covered by the present report, where the basal part is Paleocene, but most of the formation is Eocene. In the area included in the present report the Lodo (?) formation consists of a basal conglomerate overlain by glauconitic sandstone and dark sandy siltstone. The light-colored and variegated glauconitic sandstone of columns 9 and 10, assigned on Preliminary Chart 6 to the Domengine (?) sandstone, is now assigned to the Lodo (?) formation, and on the basis of foraminiferal evidence the Lodo (?) of both areas is considered Paleocene in age.

The Eocene Domengine formation of column 6 consists of fossiliferous sandstone with a basal conglomerate, overlain by grayish green foraminiferal siltstone. The fossiliferous sandstone of column 13 is referred to the Domengine (?) sandstone.

The Kreyenhagen shale—the most distinctive lithologic unit—is represented in all the sections of Figure 2, except column 6, where it is overlapped by Miocene strata. The Kreyenhagen consists of chocolate-brown and light-colored shale, a basal pebbly glauconitic sandstone being present in some sections. The formation appears to be entirely of Eocene age in this area.

PREPARATION OF SAMPLES

Fine- to medium-grained sandstones were selected at outcrop localities, with the exception that sediments of finer grain were collected at two localities (M-1, M-2 of column 6, Figure 2), where more suitable material was not available.

The following procedure was used in treating outcrop samples. They were crushed and boiled in hydrochloric acid to remove carbonate cement. This treatment removed any apatite that may have been present. The samples were then washed to remove clay and fine silt particles, and were screened on an 80-mesh screen. A measured amount of the material that passed through the screen was treated with bromoform (specific gravity 2.85) and the percentage of heavy minerals in the separate was determined by volumetric comparison with weighed samples. In each heavy-mineral fraction of outcrop samples, 200 grains were counted. The light fraction was not studied as thoroughly as the heavy. Rough estimates of occasional samples of the light fraction were made to determine relative amounts of quartz, alkalic and andesine feldspars.

Heavy fractions of mineral-grain samples from the core material had already been prepared and mounted in Canada balsam. It is not known what percentage of the total sand in these samples is represented by the heavy-mineral fraction. Frequencies of minerals were estimated, the estimates being checked by occasional counts. The counted slides included all those containing few grains.

The data obtained are shown on the accompanying tables.

MINERALOGY OF OUTCROP SAMPLES

Upper Cretaceous and Paleocene.—Sections of Upper Cretaceous and Paleocene strata near Moreno Gulch, near Ortigalita Creek, and on Orestimba Creek were sampled (columns 6, 11, and 13, respectively, of Figure 2). With few exceptions, samples from other localities represent matrix from fossil collections, as shown in Figure 2. Some samples collected for this study are duplicates of samples from matrix of fossil collections. Only one sample (CS-1-a) is from the Lodo (?) formation.

The mineral assemblages from the Upper Cretaceous and Paleocene outcrop samples are shown in Tables I–III. They are essentially the same throughout. Minor fluctuations in the amounts of individual minerals are apparent, but the changes involve only a few feet of strata and no consistent change is recognizable in adjoining sections. The percentages of hornblende, epidote, and sphene, vary through a wide range. These variations are, however, rapid throughout the section and do not permit consistent zoning on the basis of frequencies. The same is true of the less abundant minerals, such as tourmaline, garnet, and andalusite. No consistent difference is apparent between the Upper Cretaceous and Paleocene samples of Tables I–III. There is little resemblance between the mineralogy of the Martinez (?) formation of the Moreno Gulch section (Table I) and that of the Ortigalita Creek section, or of the intervening area (Tables I and II). The heavy

TABLE I
HEAVY-MINERAL SAMPLES FROM OUTCROP SECTIONS

			Approx. Percentages Light-Mineral Fraction					*Percentages of the Heavy-Mineral Fraction*																		
			Quartz	Alkalic feldspar	Andesine	"Anauxite"	Percentage of heavy minerals	Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite(?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
0.5 mile south of Moreno Gulch, Column 6 (Fig. 2)																										
Domengine formation		CR-1	50	30	20		0.5	21	13	11	13	5	5	2	6	X		4	15	1			1			Barite—P, Chromite—1%, Glauconite—P
		M-11	35	50	15		0.2	57	5	10	1		1	4	2			X	8	9			2	1	P	Chlorite—P, Piedmontite—1% Cyanite—P
Martinez (?) formation	Upper member	M-10				X	0.7	68	5	13	X		X	4	1			X	2	7			X	X	P	
		M-9					0.3	20	5	3	38		20	2	7	X			X	5			X	X	P	
		M-8	65	30	5	?	0.1	58	8	12	2			5	1				X	13	X		1		P	Hypersthene—X
		M-7					0.1	67	12	7	3		1	4	2					3			1		P	
		M-6	50	47	3	X	0.5	70	8	10	1		X	4	2				X	4	X		1	X	P	
		M-5					0.1	65	10	6	3		4	6	X			X	X	4			1	1	P	
	Lower member	M-4	55	45	X		0.2	70	8	5	2		X	6	X					5			2	2		Siderite—P
		M-3					0.3	74	3	10	5		X	4	1					3	X		X			Cyanite—X, Celestite—P
Moreno shale		M-2					0.2	60	17	6	2		1	4	3			X		3	X		X	4		
		M-1	70	25	5		0.1	55	11	5	10		1	3	0				1	4	X		1		P	
Laguna Seca Creek, Column 9 (Fig. 2)																										
Martinez (?) fm.	Upper member	F-24a	40	50	10		8.0	9		2	10		8	X	1	69		1			X		X			Glauconite—P
		F-51a					2.5	4		2	22		5	1	1	63		2		X			X	X		
	Lower member	LS-1					0.3	13		1	38		12	1	3	29		3		X			X		P	Chlorite—P
		F-90					1.0	23		4	40		20	2	4	7		X		X	X		X		P	Chlorite—P
2 miles N. of Laguna Seca Creek, Column 10 (Fig. 2)																										
Lodo(?) fm.		CS-1-a				P	1.0	47	28	10	X			4	1					8	2			X		Dumortierite—X, Siderite—P
Martinez (?) fm.	Upper member	CS-1-b	70	30	X	P	1.2	61	10	18		X	2	3	1				X	2	1		1			Monazite—X, Siderite—P, Brookite, 1%
		F-46	20	35	45		10.0	5		1	17		5	1	3	64	3	X		X		1	X			Chromite—X
	Lower member	F-23					5.0	5		1	15		4	2	2	69	1	1			X		X		P	
Moreno sh.		F-14	20	50	30	?	0.2	33	16	15	1	1	22	7	2	1		1						X	P	Chromite—1%

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

TABLE II

HEAVY-MINERAL SAMPLES FROM OUTCROP SECTIONS

	Sample Number	*Approx. Percentages Light-Mineral Fraction*				Percentage of heavy minerals	*Percentages of the Heavy-Mineral Fraction*																		
		Quartz	Alkalic feldspar	Andesine	"Anauxite"		Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite (?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
1.7 miles south of Ortigalita Creek, Column 11 (Fig. 2)																									
Kreyenhagen sh.	O-15b	70	30	X		1.7	60		33	1		X	1						1	1		2	1		Cyanite—X, Glauconite—P
Martinez (?) formation, Upper member	O-14					0.4	39		4	31		20	1	1			2		2		X	X			
	O-13					5.0	20		7	8		8	X	2	54		X		1			X			
	O-12	65	30	5		5.0	20		5	27		9	2	5	29		2		1	X		X	X		Glauconite—P
	O-11					0.6	21		3	42		14	3	5	9		3		X	X					
Martinez (?) formation, Lower member	O-10					0.8	12		5	21		4	2	4	52									P	
	O-9	35	50	15		1.5	31		3	27		21	X	7	11		X		X						
	O-8					1.0	13		3	21		8	2	5	42		6		X		X				
Moreno shale	O-7					2.0	50		15	11		3	1	6	14		X		X			X	X		Cyanite (?)—X
	O-6					0.1	35		5	36		16	4	3			1		X			X			Poor sample
	O-5	40	30	30		0.1	61		1	19		8	2	2	7		X		X	X	X	X	X		
	O-4					0.7	26		3	12		15	2	5	33		X		2	1		X			Hypersthene—1%, Chlorite—P
	O-3					0.5	38		3	20		22	2	8	3				3	1					
	O-2	30	60	10		0.2	45		4	8		32	5	4					1	X		1		P	Chlorite—P
	O-1					0.5	50		3	14		21	5	5					2			X			Sillimanite—X, Chlorite—P
	F-38					0.4	32	10	6	14	6	15	2	8				1	5	X		1		P	
Garzas Creek, Column 12 (Fig. 2)																									
Martinez (?)	G-1					0.8	11	2	1	29		8	2	4	41		2		X	X				P	Chlorite—P
Moreno formation	F-34					2.0	29	3	11	14	11	12	1	7	10		1	1	X			X			
	F-17	50	40	10		0.4	27	16	6	23	9	12	3	2				X	2			X		P	

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

TABLE III
HEAVY-MINERAL SAMPLES FROM OUTCROP SECTIONS

		Approx. Percentages Light-Mineral Fraction					Percentages of the Heavy-Mineral Fraction																		
		Quartz	Alkalic feldspar	Andesine	"Anauxite"	Percentage of heavy minerals	Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite (?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
Orestimba Creek, Column 13 (Fig. 2)																									
Domengine (?) sandstone	F-85	35	50	15	O	1.0	45	4	20	11		12	3	3	X		X		2	X		X	X		Glauconite—P, Chromite—X
	OC-10	35	60	X		1.0	57		10	2		16	4	5	X			1	2	2		1			Glauconite—P, Brookite—X
Martinez (?) formation	OC-11					0.1	43		3	25		3	3	6	17		X		X	X		X	X	P	
	OC-12	85	15		P	1.5	79		13			X	6	X					1	1		X	X		
	OC-9	20	45	35		4.0	9		1	33		7	2	2	46		X		X			X			
	F-53					1.7	13		2	41		20	4	3	16		X		1	X					
	OC-8					4.0	12		X	30		8	2	4	44		X		X	X					Brookite—X
	OC-7	20	30	50		5.0	17		2	16		9	1	5	50		X		X	X				P	
Moreno formation	OC-6c					1.5	20		2	28		14	3	6	26		X		1			X			
	OC-6b					0.5	24		2	24		6	2	4	36	1	1	X	X	X		X			
	OC-6a	35	40	25		1.0	13		2	25		8	2	4	42		2	2	X		X	X	X	P	
	OC-5					2.0	26		3	34		7	1	5	24		X	X	X			X		P	
	OC-4					2.5	15		1	42		5	2	1	34		X		X					P	Chlorite—P
	OC-3					2.0	11		1	51		4	2	2	28		1					X		P	Glauconite—P
	OC-2	30	20	50		4.0	18		2	25		9	1	2	42		1		X						
	F-29					0.2	35	10	11	20	10	8	2	3				X	1			X		P	Chromite—1%
	OC-1b					1.0	25		4	25		18	5	7	13				½	2		½			Chlorite—P
	OC-1a					1.5	37	10	10	17	5	11	3	4					2	X		1			Chromite—X
Salado Creek, Column 14 (Fig. 2)																									
Martinez (?) formation	F-55					2.8	15	1	2	25		8	2	2	44		1		X	X					Chromite—X
	F-56					6.0	10		2	35		7	1	3	40	1	1		X			X			
Puerto Creek and Black Gulch, Column 15 (Fig. 2)																									
Martinez(?) formation	PC-2	45	40	15		0.5	64		3	20		3	5	2			1		1	1		X			Cyanite—X, Chlorite—P
	BG-3	20	45	35		1.3	23		3	43		20	2	6	1		1		X	1		X			Dumortierite—X
	F-59a	25	45	30		8.0	13		2	37		12	1	4	31		X		X	X		X		P	
Moreno formation	PC-1	45	50	5		1.0	31		2	38		13	4	3	7		1		1			X		P	
	BG-2					1.0	58		4	25		2	4	3	2		X		1	X		1	X		Cyanite—X
	BG-1	30	40	30		2.5	31		3	43		11	1	6	4				1			X			

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

TABLE IV
HEAVY-MINERAL SAMPLES FROM SEABOARD-TIDE WATER ASSOCIATED-UNION'S HOWARD RANCH WELL NO. 1

		Depth of Core (Feet)	Percentages of the Heavy-Mineral Fraction: Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite (?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
Eocene	Kreyenhagen shale	4120–30	40	8		10	5	10	7	4	14				1		1				
		4133	40		X	7	2	13	8	7	17	X			2		1			P	Hypersthene—3%
		4150–55									P									P	Poor slide, Hypersthene—P
		4155–60	56		2	3		15	10	10			X	X	3	1		X			
		4165–71	55		8	5		12	8	7					5	X			X		
		4171–77	65		10	½		12	6	4					2	½		X			
Paleocene		4199–4209	37		13	5		10	6	4	17	X			3		2				Hypersthene—3%
		4222–34	37		2	26		21	6	4	2				2					P	
		4259–71	58		20			2	10	5	X				5			X			Brookite—X ("Anauxite" noted in core description)
		4283–95	20		8	15		15	4	5	20	2			1			X			Hypersthene—10%
		4306–18	24		3	40		25	3	2	X				3			X			
		4330–42	Poor slide, similar to 4306–18 feet with increase of hornblende																		
		4340–54	35		8	23		20	2	5	5	?			2						
		4366–75	22		8	15		18	4	4	25				3						Hypersthene—1%
		4475–4500	33	2	4	28		19	7	5					2					P	Hypersthene—X, Chromite—X
		4500	22		3	30		34	3	5					3						
		4600–4627	25		6	33		11	7	4	12		1		1	X					Hypersthene—X
		4729–52	20		4	41		20	6	6	2				1					P	Brookite—X
		4852–77	15		3	26		7	4	7	36	X	2							P	
		4977–5002	3		1	8		10	1	1	75		1								
		5778–88	20		3	30		22	5	4	16	X	X							P	Hypersthene—X
		5938–61	26		3	20		12	1	2	33	3								P	
Upper Cretaceous		6410–22	26			34		20	3	1	16									P	Poor slide
		6446–58	30			37		16	8	2	7									P	Poor slide
		6658–71	25		1	35		21	8	4	6									P	Hypersthene—X
		6681	Poor slide, apparently similar to 6658–71 feet																		
		6748	Slide extremely poor																	P	
		6931–36	32		4	10		33	6	5	9	X			1	X					Hypersthene—X

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

TABLE V

Heavy-Mineral Samples from Amerada's Carano Well No. 1

	Depth of Core (Feet)	Percentages of the Heavy-Mineral Fraction																		
		Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite (?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
Eocene	3553	72		7			12	3	6				X							Chromite—X
	3560	66		8	5		11	4	5				X		1		X			Chromite—X
	3577	44		4	20		20	6	6				X	X						
	3585	35		8	27		24	2	4					X			X			
Paleocene	3682	50		7	17		17	5	4					X			X			
	3716	37		11	27		18	4	2					1						
	3760				P		P												P	Very poor slide, Chlorite and Pyrite—P
	3795	33	8	5	30		15	3	3	3				X						Chromite—X, Chlorite—P
	3822	12		1	30		17	2	4	34		X								
	3857	12		1	15		19	1	2	50		X								Poor slide
	3890	15		1	20		20	1	3	40		X		X						
	3924	22		2	19		12	1	1	40		3							P	Chlorite—P
	3958	20		4	20		15	1	2	38		X		X						
	3992	30		5	32		20	5	7	1			X				X			
	4026	15	4	5	42		16	3	5	9		1					X			
	4061	10	5	2	44		8	2	5	24				X						
	4092	10		2	30		14	1	8	35										
	4126	11		1	35		10	5	5	33					X					
	4164	17		1	33		14	1	4	29		1		X	X					Green garnet or spinel—X
	4220	10		1	35		12	2	5	35		X								Poor slide
	4254	10		1	32		7	1	2	47		X		X			X			Cyanite—X
	4279	14		1	38		10	3	8	26		X		X	X	X				
	4307	11		1	41		8	2	4	33	X	X	X		X	X				Hypersthene—X
	4341	19		2	42		8	1	4	23		1								
	4375	24	2	4	35		9	1	5	20					X		X			
	4409	16		1	27		8	2	6	39		1								
	4444	22			32		5	X	1	40					X					
	4478	14		1	56		10	3	3	13				X						
	4512	32		4	30		13	3	5	13		X			X					
	4546	12		2	45		4	X	4	33				X	X					
	4571	12		1	54		7	2	4	20										
	4605	21		1	58		6	1	2	11					X					
	4671	20		2	55		3	3	7	10				X						
	4712	18		1	38		8	1	6	28		X		X	X					
	4819	25		1	34		13	X	3	24		X								
	4839	16		3	47		12	2	6	14		X			X		X	X		
	4953	13		1	56		5	4	4	17										
	5082	25		6	20		10	1	4	34										
	5177	20		2	40		14	3	6	15		X								
	5262	15		1	60		11	4	7	2		X								
	5297	15		2	40		26	3	8	6				X			X			
	5332	17		2	37		18	4	8	14					X					
	5415	20		3	49		15	1	6	6					X					
	5524	24		4	50		12	2	8			X			X					
	5582	18		1	60		12	3	6	X					X					
	5785	17		1	53		20	3	6											
	5881	19		1	59		15	1	5											
Upper Cretaceous	6105	32		2	25		30	1	10	X					X		X			
	6225	P			P		P		X											Glauconite—P, Poor slide
	6653	54		X	8		25	1	12			X								
	6807	60		3	3		20	4	10						X		X			
	6850	68		5	1		12	4	9						1					
	6915	57		1	1		19	6	16						X					Chromite—X, Glauconite—P
	6982	56		8	2		20	2	12											
	7050	80		2	1		6	3	8					X	X					
	7095	72		1	2		3	6	4						3					Chromite—1 Poor slide, 92 grains
	7155	Very poor slide																		
	7291	68		18			4	2	6						1		1			
	7355	78		12				2	8											
	7420	72		4	2			9	13											Chromite—X
	7535	77		4	X		1	4	13				X		1		X			
	7643	76		7	X		1	4	12	X				X	X		X			Chromite—X
	7696	72		9			2	4	13						X					
	7795	77		13	1			3	6				X		X		X			
	7836	76		8	X		X	5	11						X					
	7963	70		10			6	6	8								X			
	8045	81		4	X		2	8	5											
	8100	62		18	X		9	3	8				X				X			Glauconite—P
	8150	68		13	X		2	8	8						1		X	X		
	8348	70		14	1		2	5	8						X		X			
	8380–85	68		12	X			8	12						X		X			

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

minerals in the Moreno Gulch sediments are only the more stable minerals such as black opaques, zircon, tourmaline, and garnet, with hornblende and epidote generally absent or rare. The Upper Cretaceous and Paleocene from the Ortigalita Creek section and the intervening area contain epidote or hornblende in percentages ranging from 0 to 70, and show no obvious change in the content of minor minerals, except that they are less abundant in samples containing large amounts of epidote, with or without hornblende.

A white sand in the Martinez (?) formation of the Orestimba Creek section (OC-12) underlies the ledge-forming part of the lower ferruginous sandstone of Preliminary Chart 6. A similar white sand underlies the upper ferruginous sandstone of Preliminary Chart 6, 1,000 feet above OC-12, but was not sampled. According to Stewart, Popenoe, and Snavely, these beds can be traced for some miles north and south of the creek. The sampled white sand is distinctive in that it contains only the suite of stable minerals. The light fraction of this sample is mostly quartz, with alkalic feldspar and "anauxite"[4] present in minor amounts. The heavy mineral suites above and below the white sand contain 17 to 46 per cent of hornblende, 25 to 33 per cent of epidote, and considerable sphene, whereas the percentage of zircon and black opaques is considerably lower than in the white sand. The sample immediately below the white sand contains abundant alkalic and andesine feldspars, and the quartz content is low. The mineralogy of the white sand suggests a type of sediment like that in the Eocene Ione formation of the Sierra Nevada foothills. The white sand of Orestimba Creek is, however, possibly Paleocene in age. The same type of sand is present in the upper part of the section 2 miles north of Laguna Seca Creek (CS-1-a, CS-1-b, Table I) and in the Moreno Gulch section (M-6, M-10, Table I). Though hornblende and epidote are absent in all but one of the samples from the Moreno Gulch section, only M-6 and M-10 contain "anauxite."

Eocene.—As this study was undertaken chiefly as an attempt to differentiate Upper Cretaceous and Paleocene sediments, the Domengine formation, Domengine (?) sandstone, and the greensand generally present at the base of the Kreyenhagen shale were not studied in detail.

The Domengine samples CR-1 and M-11, from the Moreno Gulch section (Table I), contain a notably higher percentage of glaucophane than any other sample. They show the same relations as in the Coalinga district, 40 miles to the south, where Regan[5] found a relative abundance of glaucophane to be characteristic of the Domengine formation. The same feature was observed by White[6] in the intervening Panoche Creek area, though the change as shown in White's Table I is not as striking as that in the Coalinga district on the south or in the

[4] "Anauxite" refers to kaolinite, possibly of the anauxite type. It is now known that anauxite is not a distinct mineral, but is kaolinite with extra mixed layer sheets of silica.

[5] L. J. Regan, Jr., "Origin of the Eocene Sands of the Coalinga District, California," *California Inst. Tech., unpublished Ph.D. thesis* (1943).

[6] R. T. White, "Eocene Yokut Sandstone North of Coalinga, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 10 (1940), pp. 1742, 1750.

TABLE VI
HEAVY-MINERAL SAMPLES FROM SHELL'S CHOWCHILLA FARMS WELL NO. 74-9

	Depth of Core (Feet)	Percentages of the Heavy-Mineral Fraction																		
		Black opaques	Leucoxene	Zircon	Epidote	Zoisite	Sphene	Tourmaline	Garnet	Hornblende	Basaltic hornblende	Actinolite (?)	Glaucophane	Andalusite	Staurolite	Augite	Rutile	Anatase	Mica	Other
Eocene	3600	15		2	10		2	1	5	64	1	X		X		X				Chromite—X
	3618	15		2	10		3	1	4	65		X					X			Glauconite—P
Paleocene (?)	3640	36		7	29		17	4	4	1		X	2	X			X			
	3735	21		8	44		15	1	7	3		1		X						Cyanite—X
	3791	16		3	27		6	2	5	41	X	X		X	X		X	X	P	
	4008	20		4	22		10	1	3	40		X					X			Brookite—X
Upper Cretaceous	4831	11		5	42		16	4	7	15		X					X			
	5712	24		2	48		13	3	1	9		X	X	X			X			Glauconite—P, Collophane—P
	5716	P			P				P	P			P							Poor slide
	5800	11		1	39		25	3	7	14		X		X						
	6016	P			P														P	Poor slide
	6079	23		1	60		4	1	1	10					X				P	Brookite—X
	6131	12		1	29		24	3	5	26		X		X						
	6803	35		3	39		15	2	4	2				X					P	Collophane—P
	6831	30		2	41		14	6	6	1	X			X					P	
	6934	?		P	P		P	P	P	P									P	Poor slide
	7039	26		3	53		10	4	4										P	Chlorite—P
	7146	24		1	57		11	4	3				X						P	Glauconite—P
	7690	45		1	30		11	6	6	1			X					X	P	
	8084	48		8	6		24	4	10					X		X	X			
	8790	13		1	69		8	4	5					X						Chromite—X
	8795	40		1	51		4	2	X	2										Poor slide
	8803									P									P	Poor slide, Chlorite—90%
	8810	31		2	57		5	2	3	X				X						
	8815	23		X	64		5	2	6					X	X					
	8915	23		2	63		8	X	3			1		X						
	8923	21		1	67		8	X	3				X		X					

X = rare, one grain in several hundred.
P = present in varying amounts, not counted.

Moreno Gulch area on the north. Wilson[7] found glaucophane in the Domengine sandstone in the San Benito Quadrangle, 50 miles south-southwest of the area covered by the present paper.

The samples collected from the Domengine (?) sandstone of Orestimba Creek do not show more glaucophane than the sandstones of the underlying Martinez (?) formation, but are notably lower in hornblende and epidote. The higher sphene content and the lack of "anauxite" may differentiate the sandstones of the Domengine formation from the white sands of the Martinez (?) formation.

One sample of sandstones from the basal part of the Kreyenhagen shale (O-15b, Table II) contains a suite of stable heavy minerals; andesine feldspar is rare and glauconite is present.

MINERALOGY OF WELL SAMPLES

Seaboard-Tide Water Associated-Union's Howard Ranch No. 1.—Mineral assemblages from Seaboard-Tide Water Associated-Union's Howard Ranch well No. 1 are from cores ranging in depth from 4,120 to 6,936 feet (Table IV). The slides from the Upper Cretaceous contain few grains and the intervals between cores are large. Data based on these slides indicate that no significant change in the mineralogy is apparent in crossing the Cretaceous-Paleocene boundary. In general the minerals present and their frequency agree closely with those of the nearest outcrop section—Orestimba Creek (Table III).

Doubtfully identified kaolinite, possibly of the anauxite type, was noted in the core description of this well at a depth of 4,270 feet. The heavy minerals present in the sample from a core taken at a depth of 4,259–4,271 feet represent the suite of stable minerals. The occurrence of "anauxite" (?) and the stable minerals show a mineral composition like that of the white sand of the Martinez (?) formation of the Orestimba Creek section. Though a correlation with the Orestimba section is suggested by these relations, the Martinez (?) formation of the Orestimba Creek section includes two white sands 1,000 feet apart and only the lower was sampled.

Amerada's Carano No. 1.—Mineral-grain samples from the Amerada's Carano well are from depths ranging from 3,553 feet to the bottom of the hole at 8,385 feet (Table V). The largest interval between samples is between depths of 6,225 and 6,653 feet, which, according to Goudkoff, is just below the Cretaceous-Paleocene contact. The Cretaceous samples below 6,105 feet contain much less epidote than the higher samples, and hornblende is absent or rare. Hornblende also is absent or rare in samples from the lower part of the Paleocene, but the epidote content of the Paleocene samples in the hornblende-poor zone is very high. The significance of this change is unknown, as outcrop sections a few miles northwest (Orestimba and Ortigalita creeks) and the Howard Ranch well No. 1, about 16 miles north, show no comparable change in this part of the section. The upper

[7] I. F. Wilson, "Geology of the San Benito Quadrangle, California," *California Jour. Mines and Geol.*, Vol. 39, No. 2 (1943), p. 209.

samples low in hornblende and epidote may represent the white sands of the Martinez (?) formation or the basal sandstone of the Domengine (?) sandstone of the Orest'mba Creek section.

Shell's Chowchilla Farms No. 74-9.—Heavy-mineral assemblages from the Shell's Chowchilla Farms well No. 74-9 are from cores representing depths of 3,600 to 8,923 feet (Table VI). The data are incomplete, owing to the small number of cores from Paleocene (?) strata and to the number of slides that have few grains. The minerals present are the same as in the other sections studied. The Cretaceous samples below 6,131 feet contain considerably less hornblende than the higher samples, and contain abundant epidote, differing thus from the samples low in hornblende from the Cretaceous of the Amerada's Carano well No. 1. This change takes place about 1,200 feet below the top of the Upper Cretaceous.

NOTES ON INDIVIDUAL MINERALS

Light-mineral fraction.—Quartz and feldspars were separated by the index of refraction, combined with the presence or absence of cleavage and twinning. The light fraction was immersed in a liquid having an index of 1.54. Feldspars showing albite twinning are listed in the andesine feldspar column. Feldspars lacking albite twinning but having an index of refraction higher than 1.54 are listed in the andesine feldspar column, whereas those with an index less than 1.54 are listed in the alkalic feldspar column. Thus the alkalic feldspar column includes orthoclase, microcline, some albite, and possibly a little oligoclase. Microcline is present in small amounts in many of the samples. Plagioclase feldspar with a composition near that of albite is present, though not common, in nearly all the samples. The other plagioclase feldspars probably range from oligoclase to labradorite, with andesine most abundant. Chert, rock grains, and volcanic glass shards are present in many of the samples, but were not counted.

The term "anauxite" is used for a member of the kaolinite group of clay minerals that occurs in flakes showing a waxy luster when viewed under a hand-lens or reflecting microscope. Not all samples were checked for "anauxite," but in those that were checked, it is almost invariably associated with a suite of stable heavy minerals.

Amphiboles.—The amphibole group is divided into four types: green hornblende, basaltic hornblende, actinolite (?), and glaucophane. Green hornblende includes the green and blue-green varieties; the red-brown and brown varieties are listed as basaltic hornblende. Both colorless and pale green monoclinic amphiboles are included under actinolite (?).

The mineral composition of two samples from a fossiliferous sandstone in Black Gulch is shown in Table III. Sample F-59a consists of matrix from fossils collected by Stewart and is shown in column 15 of Preliminary Chart 6 as the lowest collection from the Martinez (?) formation. The lime content of this sample is very high and the heavy-mineral fraction makes up 8 per cent of the sand. The

other sample (BG-3) was collected from the bed where the sandstone is friable and the lime content is very low. The heavy-mineral fraction of this sample is only 1.3 per cent. The mineral content of these two samples and of sample F-59a recalculated without hornblende is shown in Table VII.

The scarcity of hornblende and the decrease in the amount of epidote in sample BG-3 confirm Bramlette's[8] conclusion that hornblende and epidote may disappear from sediments after their deposition, but may be protected from leaching solutions by cementing material. In this example the importance of surficial weathering can not be estimated, as both samples were collected near the present weathered profile. It indicates, however, that any correlations or conclusions as to source of sediment based on the absence of hornblende are subject to question.

TABLE VII

MINERAL COMPOSITION OF LIME-RICH (F-59A) AND LIME-POOR (BG-3) SAMPLES OF SANDSTONE IN MARTINEZ(?) FORMATION OF BLACK GULCH

Mineral	*F-59a (Per Cent)*	*F-59a Less Hornblende and Recalculated to 100 Per Cent*	*BG-3 (Per Cent)*
Black opaques	13	18.8	23
Zircon	2	2.9	3
Epidote	37	53.6	43
Sphene	12	17.4	20
Tourmaline	1	1.4	2
Garnet	4	5.7	6
Hornblende	31		1
Actinolite(?)	Rare		1
Andalusite	Rare		Rare
Staurolite	Rare		1
Rutile	Rare		Rare
Dumortierite			Rare
Muscovite	Present		
	100.0	99.8	100.0

Glaucophane is present throughout the area. The mineral crossite was not recognized, though it may be present and included with glaucophane. The grains counted as glaucophane, however, do not show the deep pleochroism characteristic of crossite. The presence of glaucophane in samples containing only the more stable minerals in the Moreno Gulch section suggests that glaucophane is relatively stable.[9]

Pyroxenes.—The pyroxenes are listed as two types: augite and hypersthene. Unknown colorless clino-pyroxene was noted in two samples, but, as it is rare, no attempt was made to identify the variety, and it is listed with augite.

Garnets.—The garnets were not separated as to color. The colorless variety is the most prevalent type; red, pale pink, and yellow varieties are present in

[8] M. N. Bramlette, "The Stability of Minerals in Sandstone," *Jour. Sed. Petrology*, Vol. 11, No. 1 (1941), pp. 32–36.

[9] A. O. Woodford, "The San Onofre Breccia, Its Nature and Origin," *Univ. California Bull. Dept. Geol. Sci.*, Vol. 15, No. 7 (1925), pp. 223–24.

minor amounts. One sample (Amerada's Carano, depth 4,164 feet) contains a green garnet or spinel. Strained garnets are present in most of the samples.

Zircon.—Nearly all the zircon in the samples is colorless, rarely yellow-brown. It is present in almost every sample studied as small euhedral grains.

Epidote group.—Epidote and zoisite are usually listed together, but are separated if zoisite is common. Clinozoisite is included with zoisite. Piedmontite was noted in only one sample (CR-1), which is rich in glaucophane.

Barite and celestite.—Barite was noted in a few of the samples, and the irregular shape of the grains indicates that it occurs in the interstices of sandstone. One sample (M-3) contains a considerable amount of celestite. The colorless celestite grains are oval plates, the smooth outlines of which probably were caused by the preliminary acid treatment. They tend to lie on the basal face or cleavage plane (001) and show only a trace of the prismatic cleavage. The elongation is positive and the grains give a questionable Bx_0 figure. The indices, as determined by immersion methods, are $\beta = 1.621 \pm 0.001$ and γ close to 1.629. The grains were differentiated from barite by their lower indices of refraction and from nonpleochroic andalusite by the different sign of elongation.

Andalusite.—Andalusite is present in both the Upper Cretaceous and the Paleocene throughout the area, and is especially abundant in the Moreno Gulch section (Table I), where it is associated with a suite of stable minerals. The grains are ordinarily pleochroic, but occasionally they are very pale or colorless. The negative elongation is useful in separating the colorless variety from barite or celestite.

Mica.—No attempt was made to count the mica flakes, as they are likely to be found in both the light- and the heavy-mineral fraction, and a large percentage of the micas may be lost during washing. Muscovite and biotite were noted separately but are combined in the final lists, as they show no definite trend. Muscovite is the more common variety, especially in the well samples.

Chromite.—Chromite may be present in larger amounts than is indicated by the tables, as opaque grains of this mineral were not differentiated from other black opaques. The non-opaque grains, which have a deep red-brown or brown-black color, an extremely high index of refraction, and ordinarily show the octahedral crystal form, are present throughout the area studied.

SOURCES OF SEDIMENTS

The sources of the minerals in the sediments of this area can be discussed only in a general way until more information is available on the mineralogy of the pre-Upper Cretaceous rocks in both the Coast Ranges and the Sierra Nevada.

Glaucophane is the most dependable guide for determining source rocks, as it certainly indicates a western source. It is present in the Upper Cretaceous and Paleocene, but is much more abundant in the Eocene Domengine formation in the southern part of the area. The presence of glaucophane suggests a land mass consisting of Franciscan rocks, including schist, possibly in the region of the

present Diablo Range. This land mass evidently extended a considerable distance northward from Coalinga. Piedmontite, which is associated with glaucophane in sample CR-1 from Moreno Gulch, is not listed by Taliaferro[10] as a mineral present in the metamorphics of the Franciscan formation. It is, however, a rare constituent of a Franciscan (?)-derived quartz-schist boulder in the San Onofre breccia.[11] The association with glaucophane suggests a Franciscan source, though piedmontite is known to occur in the Sierra Nevada.[12]

The source of hornblende may be the Sierra Nevada, the granitic rocks of the Gabilan Range in the Coast Ranges, or earlier Cretaceous or Jurassic sediments. The possibility that such large amounts of hornblende were reworked from Cretaceous or Jurassic sediments seems remote. Hornblende is present in Cretaceous sandstones older than those examined, but in smaller amounts than in the late Upper Cretaceous and Paleocene. As hornblende is one of the less stable minerals, it is unlikely that it was concentrated by loss of other minerals. The inferred high of Franciscan rocks in the Diablo Range on the west, between this area and the Gabilan Range, almost eliminates the granitic rocks of the Gabilan Range as a source of the hornblende. The Paleocene sediments containing large amounts of hornblende are found as far east as the Shell Chowchilla Farms well, which lies closer to the Sierra Nevada than to other source rocks. The Sierra Nevada seems to be the most reasonable source for this mineral.

The mineral chromite is common in basic igneous rocks and serpentines, and its source may have been the serpentines of the Franciscan on the west, the metamorphosed basic igneous rocks and serpentines of the Sierra Nevada on the east, or possibly both.[13]

The source of andalusite is doubtful. It is known to be present in large amounts in the Sierra Nevada and is not known to occur in possible Coast Range source rocks. The source of andalusite in the sediments on the west side of the San Joaquin Valley was considered to be Sierran by Allen.[14] Though Allen found andalusite to be absent in sediments older than those of Ione type along the west border of the northern San Joaquin Valley and in near-by subsurface sections, it is present in the Moreno (?) and Martinez (?) formations of the Los Banos district, and in the sandy matrix from Upper Cretaceous fossils collected by W. P. Popenoe on the south side of Deer Valley, in the Mount Diablo Quadrangle of the

[10] N. L. Taliaferro, "Franciscan-Knoxville Problem," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 2 (1943), p. 170.

[11] A. O. Woodford, *op. cit.*, p. 192.

[12] E. B. Mayo, "Two New Occurrences of Piedmontite in California," *American Mineralogist*, Vol. 17, No. 6 (1932), pp. 238–48.
———, "Discovery of Piedmontite in the Sierra Nevada," *California Jour. Mines and Geol.*, Vol. 29 (1933), pp. 239–43.

[13] N. L. Taliaferro, *op. cit.*, p. 158.
Cordell Durrell, "Metamorphism in the Southern Sierra Nevada Northeast of Visalia, California," *Univ. California Bull. Dept. Geol. Sci.*, Vol. 25, No. 1 (1940), pp. 78–79, 83.

[14] V. T. Allen, "Eocene Anauxite Clays and Sands in the Coast Ranges of California," *Bull. Geol. Soc. America*, Vol. 52, No. 2 (1941), pp. 271–93.

San Francisco Bay district. Regan,[15] reported andalusite to be present in the Coalinga district in sands which he believed to be derived from a western source, and suggested metamorphic rocks in the Coast Ranges as a source, since this mineral is common in metamorphosed argillaceous sediments. Andalusite, however, has not been recorded from schists of the Franciscan formation or other possible source rocks in the Coast Ranges.[16] The presence of andalusite in the Shell Chowchilla well suggests that the mineral may have been derived from the Sierra Nevada.

Much weight has been put on the presence of "anauxite" as indicative of source rocks and possibly as an aid in age determinations. Allen[17] suggests that the "anauxite" of the Ione formation and in Eocene sediments along the west border of the San Joaquin Valley is a product of extreme weathering of the basement rocks of the Sierra Nevada, and that its presence in Coast Range sediments may indicate an Eocene age. "Anauxite" has been recently recognized in the Upper Cretaceous sediments of Moreno Gulch 3,100 feet below the top of the Moreno shale.[18] Woodring and Popenoe[19] have found considerable amounts of a clay mineral identified as "anauxite" in sediments associated with clay deposits in the northwestern part of the Santa Ana Mountains in southern California. According to Woodring and Popenoe, these sediments are in non-marine strata above marine fossiliferous Upper Cretaceous strata and below beds containing marine Paleocene fossils, and are probably Paleocene in age. The "anauxite"-bearing sediments of the Santa Ana Mountains are possibly of about the same age as the white "anauxite" sands in the Martinez (?) formation in the Orestimba Creek and Moreno Gulch sections.

CONCLUSIONS

This study of the mineralogy of the late Upper Cretaceous and Paleocene sediments in the northwestern San Joaquin Valley indicates that the sediments of those ages can not be identified satisfactorily by their mineral content. The variations in mineralogy do not lend themselves to zoning in such a manner that the zones may be used for correlations between outcrop sections or to any con-

[15] L. J. Regan, Jr., *op. cit.*

[16] N. L. Taliaferro, *op. cit.* (1943), p. 170.
Parry Reiche, "Geology of the Lucia Quadrangle, California," *Univ. California Bull. Dept. Geol. Sci.*, Vol. 24, No. 7 (1937), pp. 119, 122, 124, 127.
P. D. Trask, "Geology of the Point Sur Quadrangle, California," *Univ. California Bull. Dept. Geol. Sci.*, Vol. 16, No. 6 (1926), pp. 119–186.
W. M. Fiedler, "Geology of the Jamesburg Quadrangle, Monterey County, California," *California Jour. Mines and Geol.*, Vol. 40, No. 2 (1944), pp. 178–250.

[17] V. T. Allen, "The Ione Formation of California," *Univ. California Bull. Dept. Geol. Sci.*, Vol. 18, No. 14 (1929), pp. 347–448.
———, *op. cit.* (1941).

[18] L. J. Regan, Jr., *op. cit.*

[19] W. P. Woodring, and W. P. Popenoe, "Paleocene and Eocene Stratigraphy of Northwestern Santa Ana Mountains, Orange County, California," *U. S. Geol. Survey, Oil and Gas Invest. Prel. Chart 12* (1945).

siderable extent between outcrop sections and near-by wells. Changes in mineral composition of the sediments in the Amerada's Carano well No. 1 and the Shell's Chowchilla Farms well No. 74-9 occur at no known geologic boundary, and the changes seem to be of a local nature and can not be identified in near-by outcrop sections.

The white sands in the Martinez (?) formation of the Orestimba Creek section and the Moreno Gulch section indicate that sands of Ione type may have been deposited in this district during Paleocene time. A subsurface sand of Ione type in the Seaboard-Tide Water Associated-Union's Howard Ranch well may be a correlative of a similar sand in the Martinez (?) formation of the Orestimba Creek outcrop section.

The minerals present appear to have been derived from both eastern and western source rocks.

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SUBMARINE SLUMPING AND LOCATION OF OIL BODIES[1]

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ABSTRACT

The lessons of submarine slumping do not appear to have been utilized much in the past, to the advantage which they might, in assisting both field and laboratory geologists in the survey, measurement, and appraisal of possible oil structures. A study of the paleogeographical implications of slumping leads to the conclusion that it may actually be an associated factor in the formation of oil. Typical examples of oil mother rocks are found in the Tertiary of the Carpathians and Caucasus, and a probable example of oil in the process of formation is to be seen in the Black Sea to-day; both are scenes of an enormous amount of submarine slumping both in the past and in the present.

INTRODUCTION

The thoughtful oil geologist is always on the look-out for anything which may expand the field man's "stock-in-trade." Likewise, the man of theory can not afford to ignore any practical aspect of geology which may have some bearing on the endless quest for new oil fields. Thus, the sedimentary process known as "submarine slumping," which has received relatively little attention outside academic circles in the past, may be applied to the study of geosynclines and basins and, in conjunction with the other evidence, it may be possible to predict on the one hand the directions of shorelines and platforms and on the other hand the areas of thick accumulation of oil mother rock.

The method of working out regional paleogeography from well logs has long been in use, but some of the unaccountable "thickenings" and "thinnings," encountered in that work, may be explained by the slumping process.

The cause of submarine slumping is the influence of gravity, which has been found to set unconsolidated sediments in motion down even a gentle slope. Milne (1897), Heim (1908), and Arkhanguelsky (1930) have independently demonstrated that angle to be as low as 2° or 3°. They also say that gravity slumping is inevitable with normal sediments on a slope of 5°. Sliding should take place therefore into geosynclines and even into gently subsiding basins.

EVIDENCE IN FIELD

In the mapping of major geological structures, the field geologist often finds unaccountable little disturbances which appear to have nothing to do with the main issue. These may be small-scale gravitational folding phenomena. The general form of these submarine slump structures is two-fold.

a. *Intercalated, intraformational contorted zones, wedged between parallel undisturbed strata.*—These intraformational folds are of many different types, but are commonly cut off at the top by a contemporaneous erosion plane. They generally have a slip plane at the base. If they have not occurred at the surface, they

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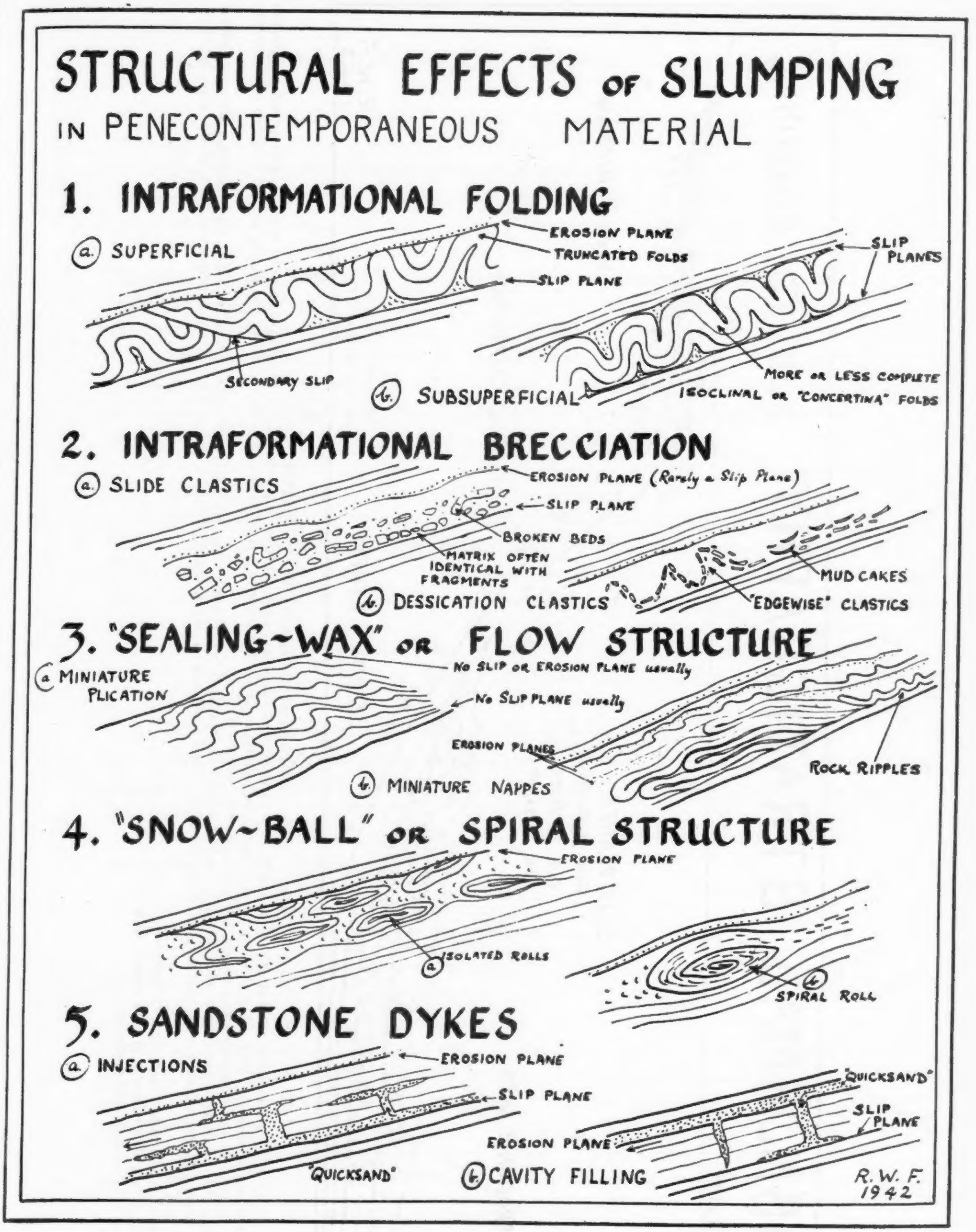

FIG. 1.—Structural effects of slumping.

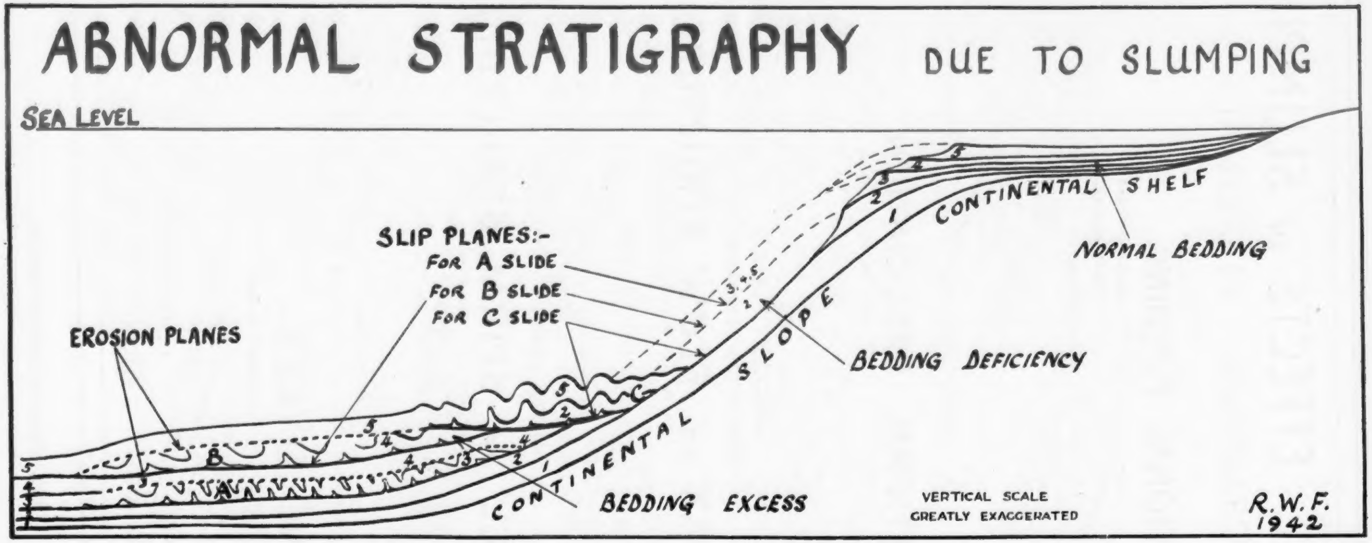

FIG. 2.—Abnormal stratigraphy, due to slumping.

We see here three sets of slumped strata, A, B, and C. The three slides took place at intervals, in this order. After the deposition of beds 1, 2, and 3, bed 3 slumped down over bed 2 (slide A). Bed 4 was then laid down, being deposited partly on the slightly eroded tops of the slide A folds and partly on bed 2, which was now exposed in part after the slumping away of bed 3 which formerly covered it.

Bed 4 then slumped down over itself (slide B). On this was next deposited bed 5, which also lay partly on bed 2, which was thus again exposed after two slides over it. When bed 5 slumped down it carried part of its substratum (bed 2) with it (slide C). Between beds 2 and 5 of the latter is preserved part of the slip-planes of slides A and B.

Slide A is a simple "concertina" crumple.
Slide B is a slipped sheet or miniature "nappe."
Slide C is a compound example.

may lack an erosion plane above and instead may show an upper slip plane. Most of them, but not all, are overturned in a certain direction, down the original slope.

b. *Sedimentary, intraformational breccias and conglomerates.*—These, too, are intercalated between parallel strata of undisturbed nature. They also represent small submarine landslides but are more fragmented, while those in group *a* have remained coherent. The material of the breccias or conglomerates is more or less of the same composition and of the same age as the surrounding beds. It may, however, be of a different but contemporaneous facies. With the contemporaneous fragments, a certain directional tendency may be identified. Breccias and conglomerates of older material may also become involved in submarine landslides, but as in this connection a series of other important conditions is involved, such as submarine landsliding from submarine fault scarps, nappe brows, *et cetera*, this question is ignored in the present paper.

There are variations and other types which are of inferior importance, but worth mentioning briefly for the sake of completeness (Fig. 1). First, there is a structure known as "*sealing-wax flow*"; in this there are no sharply defined slip planes at the base, or contemporaneous erosion planes at the top, simply a zone of highly fluid contortion in an otherwise normal series. Secondly, there are "*snow-ball*" or "spiral structures"; these commonly include a core of breccia and have a "rolled-up" appearance. As with "sealing-wax" structures, they are overlain and underlain by a normal sedimentary succession. Finally, "*sandstone dykes*," common in regions with slumping, appear to be associated also with contemporaneous movement.

In addition to these simple types of slumping, there are *compound slumps*, which may involve several successive formations. In this way, occurs the marked stratigraphic anomaly of older beds overlying younger. Several repetitions may take place.

When mapping, the field geologist should watch, therefore, for the following stratigraphic abnormalities (Fig. 2).

1. Abnormal increase in thickness (stratigraphic or bedding excess)
2. Abnormal decrease in thickness (stratigraphic or bedding deficiency).
3. Superposition of slightly older on slightly younger beds
4. Pseudo-unconformities, where horizontal beds lie on pene-contemporaneous folds
5. Pseudo-conformities, where the slip has caused a short hiatus, horizontal beds being overlain by horizontal

Certain structural phenomena somewhat similar to the foregoing may provide some confusion. *Drag folding* has been clearly differentiated from slumping by Nevin (1936). Likewise *enterolithic folding*, due to chemical expansion (Grabau, 1913). Structures due to *ice drag* or *hill creep* will not as a rule be overlain by contemporaneous strata.

Lastly, there is *tectonic gravitational sliding*. The boundary between large-scale compound slumping and small-scale tectonic slides may be difficult to identify, since the matter is largely one of degree. Both processes are gravitational, and if the tectonic type occurs below the sea-level, the youngest beds to be af-

fected by it will be almost contemporaneous with the beds which will be laid down on top of the disturbance (for example, in the Alpine Flysch). The difference will be well marked, however, if the sliding takes place above sea-level, since subaerial erosion and a marked hiatus will intervene before the succeeding strata are unconformably laid down.

The *orientation of the slumps* should give the field man an indication of the direction of the slope and thereby the approximate boundary of the adjacent platform or shoreline. Considerable thinning should be measured in that direction, with excessive thickening down the slope. Thus a section measured on the

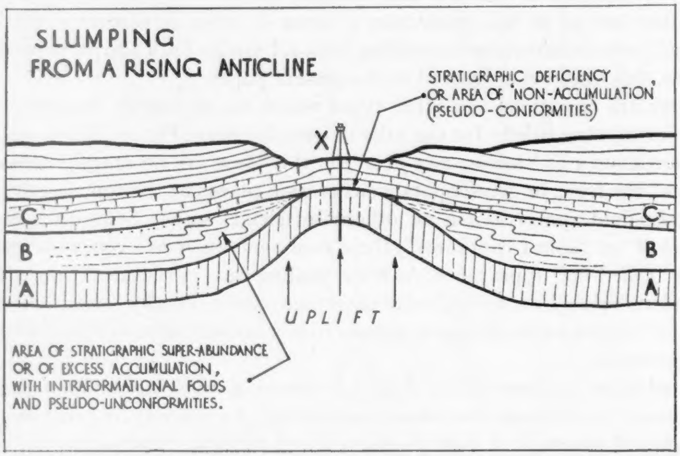

FIG. 3.—Diagram to illustrate submarine slumping, pene-contemporaneous with the sedimentation, off the sides of a rising anticline or dome, inspired by an actual field example. Deep test well at X passed through formations A and C only, although B had been found well represented on the flanks. Small intraformational disturbances in formation B gave indication of slumping from the anticlinal crest.

surface across the strike containing these structures should be regarded with suspicion. This would be particularly important on the sides of an anticline, which is suspected to have been rising during sedimentation. The section measured on the flanks will give no idea of the true thickness over the crestal axis, since greater or smaller quantities of sediment may have slipped down from here.

A considerable amount of attention has been paid to differential compaction over domes (Hedberg, 1926; Nevin, 1936), but it may be well to consider the possibility of contemporaneous slumping. The result will be the same: abnormal thinning on the domes, abnormal thickening in the troughs. With advanced contemporaneous slumping over a rising anticline, it is quite possible that an entire formation can have slipped away off the crest, although no trace of such a hiatus is immediately apparent from the structure.

This is where careful field-work may be well rewarded in the subsequent drilling. Where a thinning on the top of the dome is suspected, a geophysical survey should be able to clinch the matter (Fig 3).

In geological descriptions, we often read of "an area of non-deposition." This should really be called "area of non-accumulation," because chemical and organic sediments are falling on the bottom of the ocean almost everywhere. Merely in some places, they do not stay very long. This removal is often attributed to currents, no doubt very rightly, but it may be well to consider, when we encounter a hiatus in a normal stratigraphic succession, if in fact it may not represent a slump gap. This was referred to previously as a "stratigraphic deficiency" (Heim, 1908).

If we have thinning on the top of a dome it may be well to look for thickening on the flanks. If these are slumped beds, it is not impossible that they may be suitable reservoir rocks, while the crest of the anticline is barren.

EVIDENCE IN LABORATORY AND LIBRARY

Just as in the field, a small paradoxical piece of evidence may often be ignored on the assumption that it will not affect the main issue. These scraps of evidence may confront either the paleontologist or the sedimentary petrographer. As was hinted before, the slumped material may be of a different, but contemporaneous facies, identifiable either from the lithologic character or from the fauna (especially Foraminifera) or both. This should be a comparatively simple matter for experienced men in a well known region. In a new area, however, such intercalations are likely to cause havoc in the preliminary sections, and may also lead to erroneous paleontological conclusions.

Examples of displaced facies are well known in the oceans to-day. F. X. Schaffer (1916) noted that the ship *Travailleur* dredged up patches of coarse detrital material from depths of 500 to 900 meters off the coast of Portugal although the normal sediment there was fine mud. The contrast of this littoral detritus with a shallow-water, soft-shelled fauna, buried in a deep-sea ooze was naturally most striking. E. Philippi (1908) noted sands with terrigenous minerals at depths of more than 12,000 feet in the South Atlantic. He also noted in certain places that the carbonate content of sediments increased with depth, quite the opposite to the rule based on the *Challenger* results (Murray). Similar experiences were had by Pratje on the *Meteor* expedition. Kuenen, in East Indian waters, observed that "the main influence of a steep slope on the sea bottom is the help it gives to the sliding of carbonate-rich sediments into deeper regions, when a lower percentage would prevail if the deposits had gradually accumulated *in situ*" (in: Trask, 1939, p. 353).

Horn (1915) and Escher (1916) went so far as to say that geosynclines would be completely filled by this slumping process. They based their views on the fact that certain oceanic troughs, like the Riukiu and Philippine deeps, instead of being filled with abyssal red mud, are actually covered in places with bathyal blue

mud. It is possible, however, in the case of these fine sediments that gravitational density currents carried out part of this abnormal distribution rather than gravitational slumping. Even the abyssal sands may be distributed by local currents, set up by those great tidal waves known as *tsunamis*, which in turn are caused by slumping, submarine eruptions and other disturbances.

Nevertheless, practical experience shows that slumping plays a big part in bringing contrasting facies into juxtaposition. Slump structures were found in the North Atlantic deep-sea cores. Bramlette and Bradley (1940, p. 16) found here Foraminifera of warm-water and cold-water type in juxtaposition and attributed it to slumping. Revelle and Shepard (in: Trask, 1939, p. 260) remark that "on steep slopes where submarine landsliding and slumping of sediments may occur, these different assemblages [of widely varying foraminiferal species] may be found superimposed on each other in the same short core sample." The best fossil example of displaced facies as a result of slumping was found by Bailey and Weir (1932) in the Jurassic of Helmsdale, Scotland, where corals from the shallow water had been carried down with the slides into the muddy deeper-water facies. Bailey, Collet, and Field (1928) described another at Quebec, while F. X. Schaffer (1916) described examples from Piedmont and the Vienna basin.

REFLECTIONS ON THE FORMATION OF OIL

As regards the origin of oil, many geologists, including van Waterschoot van der Gracht (1938), regard Krejci-Graf's "Euxinic" facies as one of the two main source beds (the other being the "Saline" facies), and it is precisely in the Black Sea, the type area for "Euxinic" facies, where there are the best examples of submarine slumping actually going on to-day (Arkhanguelsky, 1930). The Russian oil fields of the Caucasian foothills are also found with these "Euxinic" facies, and here too there are numerous examples of contemporary slumping (Kugler, 1939). By "Euxinic" facies is meant a confined-sea environment of reduced salinity where there is only sufficient aeration for normal life to exist in the surface waters, and anywhere below a few hundred feet is poisoned by sulphur bacteria. Thus, when dead organic matter falls to the bottom it does not decay, but accumulates in a "sapropel" or highly organic ooze (up to 35 per cent). It has been postulated that in past geological history at certain periods in particular there were far greater deposits of sapropel material than to-day.

In order to permit natural distillation to begin, it would be necessary to bring about the burial and sealing-up of this organic matter. The rapidity of such a process would be the key-note of its success. If the sapropel is not quickly entombed, geological movements might at any time bring it out of this anaerobic environment, exposing it to the normal decay bacteria. And that is where repeated submarine slumpings might play an important part. On the margins of the Black Sea to-day, there is continuous slumping going on, while repeated earthquakes in that region act as "triggers" for major submarine slides. Thus, it is that slumping processes to-day are continuously entombing "Euxinic" sapropel,

which may well become, by natural distillation, the oil of tomorrow. And, as Lyell taught, the study of the present is the key to the past.

In other areas to-day, where there is a normal benthonic development of life, there is not nearly so much organic matter available as in "Euxinic" facies, but nevertheless a greater quantity than is found in normal recent sediments (Trask gives only 2.5 per cent as an average figure for the latter). The reason for its disappearance is the activity of decay bacteria and other scavenging organisms. Frequent slides, however, will bury whole benthonic communities and preserve them from decay under anaerobic conditions. Heim (1908) gave an example of this destruction of benthonic life. In this way, organic matter in normal facies may also become converted into oil.

The geographical distribution of oil fields is not haphazard. They say "gold is where you find it," but primary oil accumulation is restricted to definite areas—two types of paleogeographical and structural province: (1) in the foredeep areas of geosynclinal belts, and (2) in the basin areas of semi-mobile epicontinental shelf regions.

The *foredeep* oil fields are those found in the ever subsiding troughs at the foot of newly rising mountain chains, where extremely rapid sedimentation takes place. Here form not only basins which are suitable for the development of the "Euxinic" facies favorable for oil formation, but the steep slopes are provided, which engender submarine slumping. Throughout the foredeep zones of the world, examples of slumping are known and numerous important oil fields occur in them, for example, the Russian Caucasus, the Carpathians, Alberta, California, Iraq, Iran, and Burma. The foredeep oil fields of Venezuela and Trinidad (Lehner, 1935) contain some of the best known examples of slumping; likewise in Ecuador, though here the situation is further complicated by tectonic gravitational slides (Barrington Brown, 1938). Many signs of slumping are indicated in the rich foredeep fields of Sumatra (van Bemmelen), and likewise in the younger Tertiary southern foothills area of New Guinea. But it should not be necessary go farther than California to find examples.

The foreland *basin* type of sedimentation also provides the right environment for oil development and many of the best oil fields are in these less disturbed regions. Slumping is not to be expected here on the large scale of the foredeep belts, but the margins of each basin and adjacent dome are commonly steep, and possibly faulted, and along these boundary zones slumping of contemporaneous sediments is encountered. In the Mid-Continent basins there are many folds or domes which thin on the crest and thicken on the flanks; unconformities near the crests are common. Such features have been explained variously by differential compaction, compression, torsion, progressive local uplift; if the last-mentioned is in any way true, as seems likely, then contemporaneous submarine slumping is to be expected. It would thus be a matter of great interest if these little "sedimentary" structures are found here in any number, and, in particular, in formations suspected of being original oil mother rocks.

Finally, a word on gravitational movements on a large scale. The question of sliding on a tectonic scale was raised earlier in the paper. Either regional sliding or compression, occurring subaqueously, will have the effect of leaving a record in the contemporary sedimentation. If the process is gradual the result will be a thickening in the synclines with an increase in the degree of folding with depth, as has been noted in the Ruhr Carboniferous area (see Lehmann, Bottcher, and, especially Stach, 1932). Stutzer (1930) has noted how subsidence, leading to tectonic folding contemporaneous with the sedimentation, has taken place in many oil fields, including the Vienna basin, at Baku in Russia, in South Rumania, and in the Polish Carpathians. These areas also contain typical slumpings. Large-scale subaqueous tectonics are inevitably accompanied by small-scale slumping and thus the two may be inextricably bound together.

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CONODONTS AS PALEOZOIC GUIDE FOSSILS[1]

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ABSTRACT

Charts showing the sketches and stratigraphic ranges of 80 conodont genera are accompanied by a discussion on methods of identifying and interpreting conodont faunas. A check list of conodont generic names is included with some suggested consolidations of generic terms. The Devonian aspects of the conodont faunas from the Chattanooga black shale and its correlatives are emphasized.

INTRODUCTION

The purpose of this paper is to outline the stratigraphic ranges of conodont genera with a discussion of the practical application and value of these fossils in determining the ages of Paleozoic rocks. The main body of the paper is found on two charts (Figs. 1 and 2) showing the sketches and ranges of conodont genera. In the discussion are valuable hints on methods of identifying genera and some concepts important to the stratigrapher who seeks to use conodonts as guide fossils.

Future research will undoubtedly reveal many new faunas and will indicate a greater stratigraphic range for some genera. However, the development of knowledge concerning conodonts has reached a point where a synthesis work of this type will increase the usefulness of these fossils to stratigraphers.

PROCEDURE IN GATHERING DATA FOR CHARTS

The accompanying charts represent a condensation made from a card index of more than 1,500 conodont species. This card index was prepared by examination of the 180 or more articles written about conodonts. More than 100 of these deal with the stratigraphic occurrence and description of species and genera. Each of these articles was reviewed for details on stratigraphy and generic identifications. Where obvious errors were present, appropriate notes were added to the species or genus cards. The generic ranges were then taken directly from the cards and plotted to a standard stratigraphic section. The best correlations available were used. Each genus was first placed in the proper conodont group and then the genera of each group were arranged in order of earliest stratigraphic appearance. As a matter of rechecking, each conodont paper was then reviewed with the charts at hand to determine any discrepancies.

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[2] Stanolind Oil and Gas Company. It is with deep appreciation that acknowledgment is made to the writing and teaching team, E. B. Branson and M. G. Mehl, of the University of Missouri, Columbia, Missouri. Certainly the basic research and broad general philosophy concerning conodonts that they have so generously given to their students and to the literature can not be over-evaluated. Special thanks are due G. A. Muilenburg, of the University of Missouri School of Mines and Metallurgy, Rolla, Missouri, for his criticisms of the manuscript and personal encouragement during the preparation of the paper. Sincere appreciation is extended to Miss Love Howard, of the Atlantic Refining Company, Midland, Texas, for her care and artistry in making the sketches.

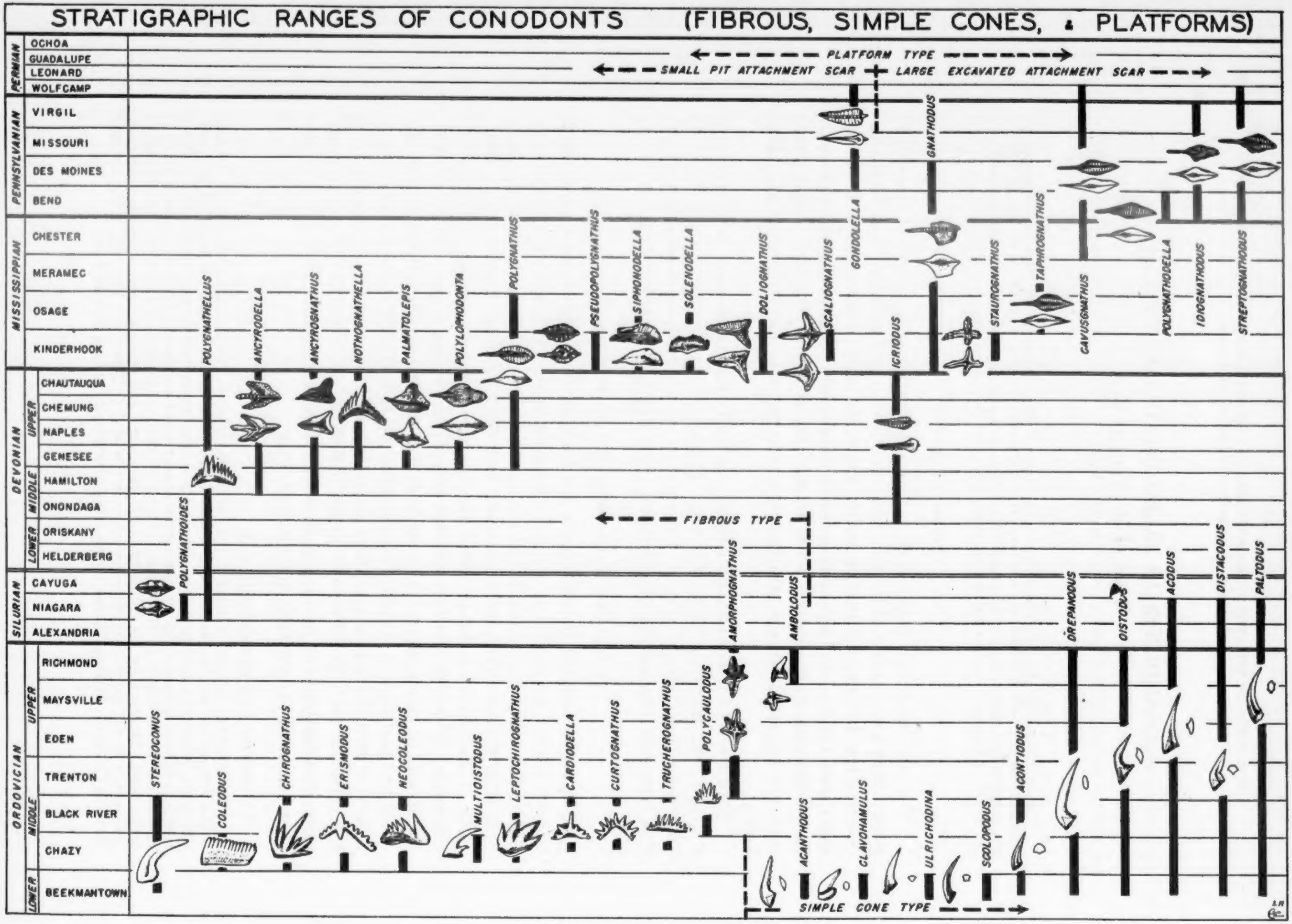
STRATIGRAPHIC RANGES OF CONODONTS (FIBROUS, SIMPLE CONES, & PLATFORMS)
PERMIAN
OCHOA
GUADALUPE
LEONARD
WOLFCAMP
PENNSYLVANIAN
VIRGIL
MISSOURI
DES MOINES
BEND
MISSISSIPPIAN
CHESTER
MERAMEC
OSAGE
KINDERHOOK
DEVONIAN
UPPER
CHAUTAUQUA
CHEMUNG
NAPLES
GENESEE
MIDDLE
HAMILTON
ONONDAGA
LOWER
ORISKANY
HELDERBERG
SILURIAN
CAYUGA
NIAGARA
ALEXANDRIA
ORDOVICIAN
UPPER
RICHMOND
MAYSVILLE
EDEN
TRENTON
MIDDLE
BLACK RIVER
CHAZY
LOWER
BEEKMANTOWN
PLATFORM TYPE
SMALL PIT ATTACHMENT SCAR
LARGE EXCAVATED ATTACHMENT SCAR
FIBROUS TYPE
SIMPLE CONE TYPE
POLYGNATHOIDES
POLYGNATHELLUS
ANCYRODELLA
ANCYROGNATHUS
NOTHOGNATHELLA
PALMATOLEPIS
POLYLOPHODONTA
POLYGNATHUS
PSEUDOPOLYGNATHUS
SIPHONODELLA
SOLENODELLA
DOLIOGNATHUS
SCALIOGNATHUS
GONDOLELLA
ICRIODUS
GNATHODUS
STAUROGNATHUS
TAPHROGNATHUS
CAVUSGNATHUS
POLYGNATHODELLA
IDIOGNATHODUS
STREPTOGNATHODUS
STEREOCONUS
COLEODUS
CHIROGNATHUS
ERISMODUS
NEOCOLEODUS
MULTIOISTODUS
LEPTOCHIROGNATHUS
CARDIODELLA
CURTOGNATHUS
TRUCHEROGNATHUS
POLYCAULODUS
AMORPHOGNATHUS
AMBOLODUS
ACANTHODUS
CLAVOHAMULUS
ULRICHODINA
SCOLOPODUS
ACONTIODUS
DREPANODUS
OISTODUS
ACODUS
DISTACODUS
PALTODUS

Fig. 1

FIG. 1

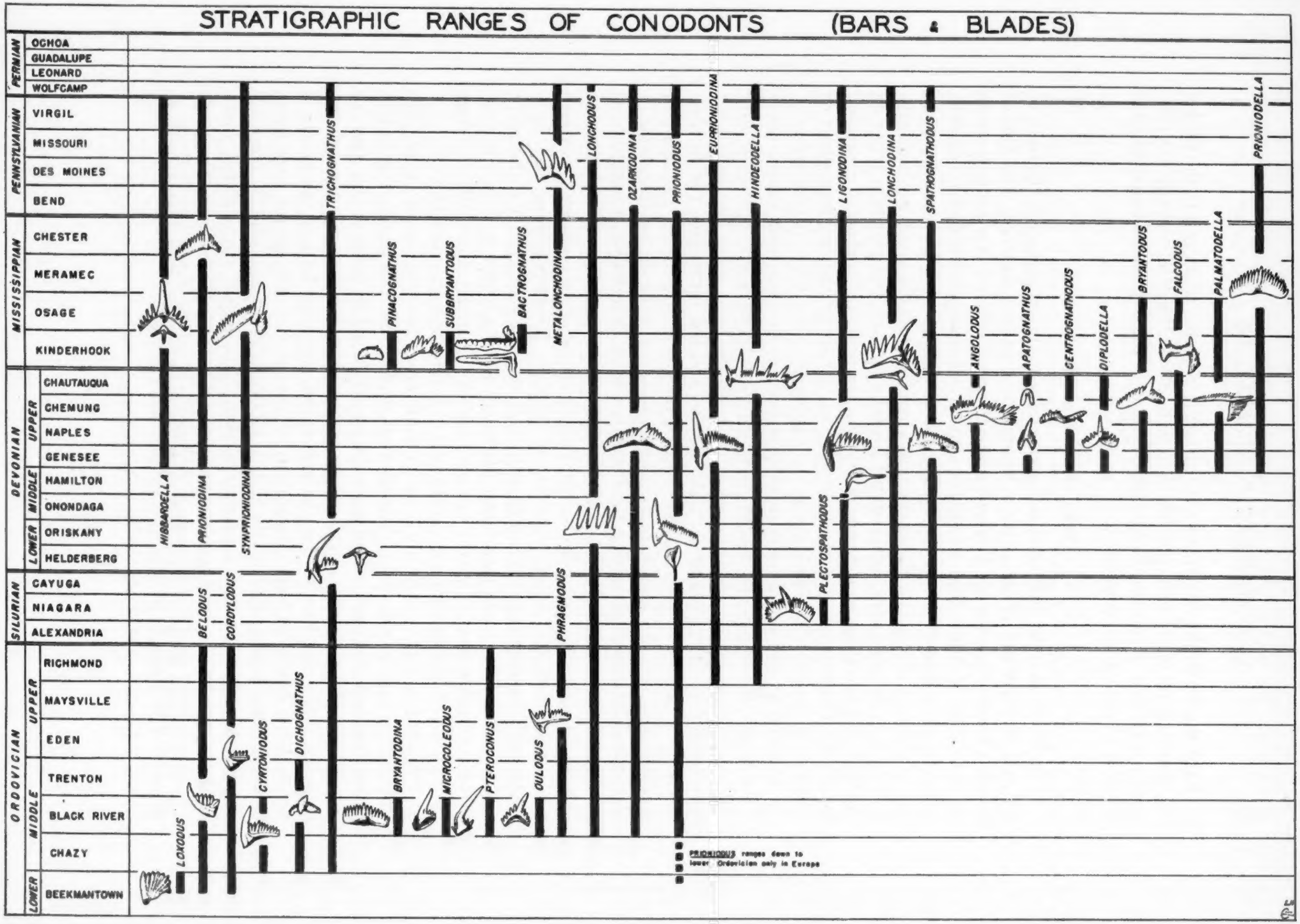
STRATIGRAPHIC RANGES OF CONODONTS (BARS & BLADES)
PERMIAN
OCHOA
GUADALUPE
LEONARD
WOLFCAMP
PENNSYLVANIAN
VIRGIL
MISSOURI
DES MOINES
BEND
MISSISSIPPIAN
CHESTER
MERAMEC
OSAGE
KINDERHOOK
DEVONIAN
UPPER
CHAUTAUQUA
CHEMUNG
NAPLES
GENESEE
MIDDLE
HAMILTON
ONONDAGA
LOWER
ORISKANY
HELDERBERG
SILURIAN
CAYUGA
NIAGARA
ALEXANDRIA
ORDOVICIAN
UPPER
RICHMOND
MAYSVILLE
EDEN
MIDDLE
TRENTON
BLACK RIVER
CHAZY
LOWER
BEEKMANTOWN
LOXODUS
HIBBARDELLA
PRIONIODINA
BELODUS
SYNPRIONIODINA
CORDYLODUS
CYRTONIODUS
DICHOGNATHUS
TRICHOGNATHUS
PINACOGNATHUS
BRYANTODINA
SUBBRYANTODUS
MICROCOLEODUS
BACTROGNATHUS
PTEROCONUS
OULODUS
METALONCHODINA
PHRAGMODUS
LONCHODUS
OZARKODINA
PRIONIODUS
EUPRIONIODINA
HINDEODELLA
PLECTOSPATHODUS
LIGONODINA
LONCHODINA
SPATHOGNATHODUS
ANGULODUS
APATOGNATHUS
CENTROGNATHODUS
DIPLODELLA
BRYANTODUS
FALCODUS
PALMATODELLA
PRIONIODELLA
PRIONIODUS ranges down to lower Ordovician only in Europe

FIG. 2

Each sketch on the charts is idealized and is intended to suggest to the reader the general form of the genus rather than to illustrate the details of any one particular specimen. Photographs and descriptions in the literature should be consulted in identification studies.

TYPES OF CONODONTS

Conodonts may be divided into fibrous and non-fibrous groups on the basis of internal arrangement of the calcium phosphate (apatite) material. The fibrous group is known as suborder *Neurodontiformes*[3] and is defined as conodonts made up of bundles of fibers. The non-fibrous group is known as suborder *Conodontiformes*[4] and is defined as conodonts composed of laminated layers rather than fibers. The non-fibrous conodonts are most abundant, and the group has been subdivided into simple cones, denticulated blades and bars, and platform types on the basis of general shape and complexity. For the practical purpose of arranging the conodont genera on the stratigraphic charts four groups are recognized as follows: (1) fibrous, (2) simple cones, (3) blades and bars, and (4) platforms.

The fibrous and non-fibrous conodonts develop in form from simple cones through the bladed and bar stages to the platform types. The simple cones give rise to blades or bars by addition of denticles to the basic cone. The basic cone becomes the apical or largest denticle. Bladed and bar forms give rise to platforms by a process of lateral thickening of the blade or bar. For example, all gradational forms are known from *Spathognathodus*, a blade, to *Gnathodus*, a platform. The sequence showing the transition from *Prioniodina*, a bar, to *Gondolella*, a platform, is perfect. Likewise, the transition from *Ozarkodina* to *Solenodella* is striking. Gradations occur between some of the platform types such as *Cavusgnathus* and *Polygnathodella*, or between *Streptognathodus* and *Idiognathodus*. This does not necessarily indicate that a true zoological line of descent exists between the genera mentioned. However, the shapes are so closely related that they suggest lines of ancestry. Such excellent examples of evolution impress the idea that conodonts are among the best of fossils for family tree studies.

Fibrous conodonts.—The fibrous conodonts range from the lower Ordovician through the upper Ordovician. The greatest deployment was during the middle Ordovician and the most useful guide forms are found in rocks of this age. Although this group shows evolutionary sequences from simple cones through the complex blades and bars to the platform types, the great bulk of the genera is denticulated blades or bars. *Stereoconus* represents the only simple cone form. *Multioistodus*, bearing one or two additional denticles, is only slightly more advanced. *Chirognathus* and *Leptochirognathus*, handshaped denticulated units mark a characteristic zone in the lower part of the middle Ordovician. The single

[3] E. B. Branson and M. G. Mehl, "Conodonts," in *Index Fossils of North America*, by H. W. Shimer and R. R. Shrock, p. 237. John Wiley and Sons, New York (1944).

[4] E. B. Branson and M. G. Mehl, *op. cit.* (1944), p. 239.

platform representative is ***Amorphognathus*** of middle and upper Ordovician. This genus probably represents the climax of specialization in the fibrous group.

Identification of the various genera is approached by a study of the shape of the attachment scar and the arrangement, shape, and attitude of the bar and denticles. Numerous specimens of this group have been found affixed firmly to masses of bony material. This has been used as strong evidence for considering conodonts as vertebrate teeth, probably fish.

Simple cones.—This group of conodonts is called the family *Distacodidae*[5] and is the most primitive of the non-fibrous forms. The family first appeared in lower Ordovician and most of the genera are believed to have died out after Silurian times. The simple cone specimens that have been reported from younger beds than Silurian are believed to be either erroneously identified fragments of the bladed or bar types or correctly identified specimens involved in a stratigraphic admixture. The simple cones are guides to lower Ordovician rocks because the more complex conodonts had not yet appeared. They are abundant in middle and upper Ordovician but do not serve as positive guides for these beds. The simple cones are present in the Silurian and the species of those genera that range into the Silurian are difficult to distinguish from Ordovician types.

Identification of each genus is based upon the shape and depth of the attachment scar and the shape of the transverse cross section of the cone. Ornamentation and curvature of the cone is used to separate some genera.

Blades and bars.—This group includes two complex families, the *Prioniodidae* and *Prioniodinidae*[6] both embracing many long ranging, very abundant bars and blades. Some of the genera have a degree of usefulness if the required amount of caution is exercised in making stratigraphic determinations. As shown in Figure 2, an important group of these genera is particularly characteristic of Ordovician rocks. Among this group are *Belodus*, *Cordylodus*, and *Microcoleodus*, which are significant because they are only a few denticles removed from the simple cones. They probably represent the most primitive blades and bars. A small group in-including the bizarre forms of *Apatagnathus* and *Centrognathodus* is exclusively upper Devonian in age. Similarly a small group including *Pinacognathus*, *Subbryantodus*, and *Bactrognathus* is known only from the Mississippian. In contrast to these restricted genera, most of the bladed and bar types found above the Silurian belong to one of the common long ranging genera with no particular value as stratigraphic markers except in a broad sense. Certain species among these genera have useful guide values but many of the genera range across two or more system boundaries without faltering.

Identification of genera is based mainly on the shape of the denticulated blade

[5] E. O. Ulrich and R. S. Bassler, "A Classification of the Tooth-Like Fossil Conodonts with Descriptions of American Devonian and Mississippian Species," *Proc. U. S. Nat. Museum*, Vol. 68, Art. 12 (1926), p. 6.

[6] E. O. Ulrich and R. S. Bassler, *op. cit.* (1926), pp. 7, 15.

or bar and the character of the denticle arrangement. Some genera may be distinguished on the character of the attachment scar. However, most of the blades and bars have attachment scars of similar shape. The scar consists of two parts, a pit or excavation directly beneath the largest or apical denticle, and an extension of this pit as a groove or a slit along the bottom side of the bar or blade to the extremities of the two or more limbs. This basic pattern of the attachment scar is important because it is transplanted intact with only slight modification into the platform group.

Platforms.—This group represents the most highly specialized type of conodont. It includes two distinct families, the *Polygnathidae*,[7] with a small pit attachment scar, and the *Gnathodontidae*,[8] with the large excavated cup-like attachment scar. The *Polygnathidae* range from middle Silurian to middle Mississippian and the *Gnathodontidae* range from the middle Devonian to Permian. Most of the genera in each of these families are remarkably restricted in stratigraphic range. These are without question the most valuable guide conodonts in beds younger than Silurian. *Polygnathellus* is the only genus in this group that crosses the Silurian-Devonian boundary. *Polygnathus* is the only genus that crosses the Devonian-Mississippian boundary. *Gnathodus* and *Cavusgnathus* extend through the Mississippian-Pennsylvanian break. *Cavusgnathus*, *Streptognathodus*, and *Gondolella* all pass from Pennsylvanian into Permian. All other genera appear to be confined to a single period or in some cases to a part of a period.

Identification of genera is based on the general shape of the platform and the shape and arrangement of the attachment scar. The differences in ornamentation on the upper or oral surfaces of the platforms are means of differentiating some of the closely related genera.

ORIENTATION OF CONODONTS

The lack of knowledge concerning the shape and size of the conodont animal body has created a problem in orienting the specimens. Most writers have avoided serious controversy by orienting the specimens under temporary rules for descriptive purposes only. Under this system there is fair agreement that the points of the denticles are upward (oral) and the attachment scar is downward (aboral). The denticles of both the simple cones and the bars and blades are curved or inclined backward (posterior). The blade end of the platform specimens is forward (anterior) and the convex curvature of the longitudinal axis of a bar, blade, or platform is the outer side. The terms right and left have been used but since conodonts are probably paired the terms upper or lower might be just as applicable.

[7] E. O. Ulrich and R. S. Bassler, *op. cit.* (1926), p. 43.

[8] E. B. Branson and M. G. Mehl, *op. cit.*, (1944), p. 245.

MIXED FAUNAS

The problems of mixed conodont faunas have repeatedly been emphasized by Branson and Mehl.[9] Their treatment of these problems and the introduction of the ideas of stratigraphic leaks and stratigraphic admixtures are of the utmost importance from a basic philosophical point of view to the stratigrapher who wishes to put conodonts to a practical use.

Stratigraphic leaks.—Stratigraphic leaks are defined as situations wherein conodonts of one age are introduced into conodont-bearing beds of an older age by infiltration along with the deposits made in solution channels and caverns. The resulting total fauna represents a confused picture suggesting two or more ages. The examples cited by Branson and Mehl[10] include: an upper Devonian fauna in clay bands cutting across Silurian beds in northeast Missouri; a Mississippian fauna in clay pockets in the Joachim (middle Ordovician) formation of central Missouri; and, a Pennsylvanian fauna in a solution-channel filling of Mississippian rocks in central Missouri. The Mississippian fauna found in the fissure fillings in the Niagaran (Silurian) of Illinois indicates a similar situation.[11] Likewise, Barnes *et al.*, have recently pointed out a circumstance where they find a Simpson (middle Ordovician) conodont fauna well down in the Ellenburger group (lower Ordovician).[12] Simpson is not known to be exposed in the vicinity and it is suggested that these fossils may be "ghosts" or "phantoms" of a formation that once existed in the area. This is a slightly modified meaning for the term "phantom" which was introduced by Branson and Mehl[13] and applied to the detection of formerly existing formations in a stratigraphic admixture.

The interpretation of stratigraphic leaks and their faunas does not enter greatly into the problem of constructing the accompanying charts because no extended research paper has yet described in detail a recognizable fauna of this sort.

Stratigraphic admixtures.—Stratigraphic admixtures have been defined as situations wherein conodonts of older sediments have been redeposited along with the conodonts of younger beds. The older fauna may actually consist of conodonts imbedded in pebbles of a conglomerate in the younger formation. However, conodonts are rather resistant to chemical weathering because of their phosphatic composition and it is not necessary that they be present as inclusions in the peb-

[9] E. B. Branson and M. G. Mehl, "Conodont Studies," *Univ. Missouri Studies*, Vol. 8 (1933), pp. 10, 14, 16, 175, 265–67.
E. B. Branson and M. G. Mehl, "The Recognition and Interpretation of Mixed Conodont Faunas," *Bull. Denison Univ.*, Vol. 35 (1940), pp. 195–209.

[10] E. B. Branson and M. G. Mehl, *op. cit.* (1940), pp. 206, 207.

[11] Carey Croneis and H. W. Scott, "Scolecodonts and Conodonts from the Fissure Fillings in the Niagaran of Illinois," *Bull. Geol. Soc. America*, Vol. 44 (1933), pp. 207, 208.

[12] V. E. Barnes, P. E. Cloud, Jr., and L. E. Warren, "Devonian of Central Texas," *Univ. Texas Bull. 4301* (1945), p. 176.

[13] E. B. Branson and M. G. Mehl, *op. cit.* (1940), pp. 208, 209.

bles of a conglomerate. The individual conodont can easily become a part of the detrital material reworked into the beds of a younger deposit. The determination of the age of the strata in a problem of this sort is based on the new types of conodonts introduced along with the reworked specimens. The recognition of these new elements presupposes a thorough knowledge of the older faunas. This is analogous to well log descriptions of rotary cuttings where the individual sample is interpreted on the basis of the new additions rather than on the total composition.[14]

Most writers have been fortunate to have obtained pure faunas or have described only what they believed to represent pure faunas. However, a number of controversial faunas have entered the literature and the discussion below indicates the interpretations accorded each of these problems.

The Glenwood fauna of Minnesota[15] includes lower middle Ordovician forms along with typical Plattin (middle middle Ordovician) fauna. These older forms are interpreted as having been added to the basal Plattin sediments by the reworking processes of the advancing Plattin seas over the older rocks. The Glenwood fauna contains abundant *Chirognathus*, *Oistodus*, *Paltodus*, and *Phragmodus*. Branson and Mehl[16] point out that the *Chirognathus* zone, characteristic of the Harding sandstone of Colorado and the McLish of Oklahoma, does not overlap the zone of abundant *Oistodus*, *Paltodus*, and *Phragmodus*. The actual occurrence records of these genera indicate that their ranges do overlap even though it is admitted that the *Chirognathus* zone is below the zone where the other genera are particularly abundant. For example, *Oistodus* and *Paltodus* have been described from the Jefferson City group of Missouri.[17] The same genera have been figured from the Prairie du Chien beds of the Upper Mississippi Valley[18] and from the Marathon beds of southwest Texas.[19] In each of these instances the genera *Oistodus* and *Paltodus* are recorded below the level of the *Chirognathus* zone. For the accompanying charts the overlapping ranges of these genera are accepted and no attempt is made to interpret the low-level occurrences of *Oistodus* and *Paltodus* as stratigraphic leaks.

The typical Ordovician forms of *Acodus*, *Acontiodus Belodus*, *Microcoleodus*, *Oistodus*, and *Paltodus*, described from the Devonian clays of Minnesota and Iowa and from the Olentangy shale of Ohio, are interpreted as reworked specimens in a Devonian fauna.[20] The mixture of Ordovician and Devonian forms in the Mise-

[14] E. B. Branson and M. G. Mehl, *op. cit.* (1940), p. 209.

[15] C. R. Stauffer, "Conodonts from the Glenwood Beds," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 125–68.

[16] E. B. Branson and M. G. Mehl, *op. cit.* (1940), p. 201.

[17] E. B. Branson and M. G. Mehl, *op. cit.* (1933), pp. 59–62.

[18] W. M. Furnish, "Conodonts from the Prairie du Chien (Lower Ordovician) Beds of the Upper Mississippi Valley," *Jour. Paleontology*, Vol. 12 (1938), pp. 318–40.

[19] R. W. Graves, Jr. and Samuel Ellison, "Ordovician Conodonts of the Marathon Basin, Texas," *Univ. Missouri School of Mines and Metallurgy Technical Series*, Vol. 14, No. 2 (1941), pp. 3, 4.

[20] C. R. Stauffer, "Conodonts of the Olentangy Shale," *Jour. Paleontology*, Vol. 12 (1938), pp. 411–43.

ener sand and Sylamore sand beneath the Chattanooga black shale of Arkansas, southwest Missouri, and Oklahoma may be interpreted in a similar way. The Devonian fauna underlying the Cooper formation of central Missouri, likewise, contains abundant lower Ordovician specimens.[21]

The mixed fauna of the basal Mississippian Bushberg age has commanded much attention because conodonts are particularly abundant in this zone and interpretation of the age of this zone directly affects the interpretation of the age of the Chattanooga black shale beneath. The Bushberg fauna described by Branson and Mehl[22] is intimately associated with Devonian and in several instances with Ordovician conodonts. However, Branson and Mehl attempted to describe only the new forms which they believed were Mississippian in age. From this work and a previous study of the Grassy Creek (upper Devonian) fauna they delineated the Devonian and Mississippian faunas on the basis of nine guide genera. *Icriodus*, *Ancyrodella*, *Ancyrognathus*, *Palmatolepis*, and *Polylophodonta*, all platforms, are found in the Bushberg and in beds of upper Devonian age below the Bushberg. These genera are not known above the Bushberg except in a few rare instances which can be interpreted as stratigraphic admixtures. *Pseudopolygnathus*, *Pinacognathus*, *Siphonodella*, and *Solenodella*, two of which are platforms, are known in the Bushberg and upward into the Mississippian limestones but are not known below the Bushberg zone. Only one platform genus, *Polygnathus*, lived through the Bushberg to be found in beds above that zone. If this interpretation is plotted on the generic range charts it appears that the basal Mississippian represents one of the major breaks in conodont chronology in spite of the fact that representatives from above and below are mingled in the one zone.

The uppermost part of the New Albany black shale of Indiana represents a typical Bushberg mixture.[23] The fauna listed from the Little Rocky Mountains of Montana and later revised belongs to the same problem.[24]

The basal Welden fauna of Oklahoma is still another example of a stratigraphic admixture.[25] It is interpreted to be somewhat younger than true Bushberg because of the presence of many specimens of a specialized type of *Gnathodus* (*Dryphenotus* Cooper) which is found elsewhere well above the Bushberg. How-

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C. R. Stauffer, "Conodonts from the Devonian and Associated Clays of Minnesota," *ibid.*, Vol. 14 (1940), pp. 417–35.
W. L. Youngquist, "Upper Devonian Conodonts from the Independence Shale (?) of Iowa," *ibid.*, Vol. 19 (1945), pp. 355–67.

[21] E. B. Branson and M. G. Mehl, *op. cit.* (1940), p. 199.

[22] E. B. Branson and M. G. Mehl, *op. cit.* (1933), pp. 265–300.

[23] J. W. Huddle, "Conodonts of the New Albany Black Shale of Southern Indiana," *Bull. Amer. Paleontology*, Vol. 21, No. 72 (1934), pp. 1–137.

[24] M. M. Knechtel and W. H. Hass, "Kinderhook Conodonts from the Little Rocky Mountains, Northern Montana," *Jour. Paleontology*, Vol. 12 (1938), pp. 518, 519.
W. H. Hass, "Corrections to the Kinderhook Conodont Fauna, Little Rocky Mountains, Montana," *ibid.*, Vol. 17 (1943), pp. 307–09.

[25] C. L. Cooper, "Conodonts from the Bushberg-Hannibal Horizon in Oklahoma," *Jour. Paleontology*, Vol. 13 (1939), pp. 379–422.

ever, it is admitted that many forms have a Bushberg aspect and Branson and Mehl[26] use this as an example of a "phantom" formation. They interpret the fauna to be younger than Bushberg but with elements that indicate the former presence of Bushberg in the region. Probably of about the same age is a fauna described from the Llano uplift of Texas.[27] A review of the Llano region collecting localities brings out the possibility that at least three of Roundy's collections could have been mixed faunas with possible reworked Devonian and Ordovician specimens. Recent work on the chert conglomerates and conodont-bearing bone beds at the base of the Mississippian has further borne this out.[28] The remnants of two Devonian limestone and chert formations immediately below the bone beds in this area may have been part of the original source for the Devonian elements in Roundy's conodont collections.

The Ordovician simple cones described from the Pennsylvanian beds of Texas[29] and Missouri[30] appear to be fragments of some common bars and blades. The Ordovician and Devonian genera listed from the Pennsylvanian of southwest Texas are interpreted as detrital specimens in an admixture.[31]

CHATTANOOGA AND RELATED DEVONIAN CONODONT FAUNAS

The age of the Chattanooga shale and its correlatives has been a controversy in geological science for more than 30 years. The publications are not reviewed in detail here. However, there exist three present-day interpretations of the age of the Chattanooga and its equivalents. The paleobotanists, some conodont workers, and the United States Geological Survey geologists have much evidence that these formations are in the greater part Devonian in age. A number of workers, including some petroleum geologists and a few State Geological Survey men, prefer to remain neutral and classify the Chattanooga problem as Mississippian-Devonian. Many petroleum geologists, some conodont workers, and a number of State Geological Survey men believe that these beds are definitely Mississippian in age.

Unfortunately no conodonts have been recorded from the type locality of the Chattanooga black shale at the north end of Cameron Hill in the city of Chattanooga, Tennessee. Therefore, no true Chattanooga conodonts are known, as

[26] E. B. Branson and M. G. Mehl, *op. cit.* (1940), pp. 208, 209.

[27] R. V. Roundy, "The Microfauna in the Mississippian Formations of San Saba County, Texas," *U. S. Geol. Survey Prof. Paper 146* (1926), pp. 5–17.

[28] V. E. Barnes, P. E. Cloud, Jr., and L. E. Warren, *op. cit.* (1945), pp. 164–77.

[29] C. R. Stauffer and H. J. Plummer, "Texas Pennsylvanian Conodonts and Their Stratigraphic Relations," *Texas Univ. Bull. 3201* (1932), pp. 13–50.

[30] F. H. Gunnell, "Conodonts from the Ft. Scott Limestone of Missouri," *Jour. Paleontology*, Vol. 5 (1931), pp. 244–52.

[31] Samuel Ellison and R. W. Graves, Jr., "Lower Pennsylvanian (Dimple Limestone) Conodonts of the Marathon Region, Texas," *Univ. Missouri School of Mines and Metallurgy Technical Series*, Vol. 14, No. 3 (1941), pp. 1–21.

yet. Swartz,[32] in his field studies, demonstrated that at least the upper part of the type Chattanooga is Mississippian in age. There is also evidence that the younger elements at the type locality are not present farther west in the Nashville basin.

In the Nashville basin, conodonts have been described from the Chattanooga shale[33] and from the Hardin sandstone[34] at the base of the shale. Although collected at some distance from the type locality of the Chattanooga, these conodonts were assigned to the early Mississippian. For purposes of discussion in this paper the Nashville basin conodonts are considered to be the Chattanooga fauna, but the term does not imply that this fauna is present at the type locality of the Chattanooga shale.

Along with the description of the Hardin sandstone conodonts, Ulrich and Bassler described Devonian forms from the Rhinestreet (Genesee) shale of New York. Not a single species in the New York fauna was found to be common with the Chattanooga fauna. The conclusion that this was ample basis for separating upper Devonian from lower Mississippian conodonts has been quoted by many subsequent writers.

The generic determinations of these faunas are plotted in Figure 3. Ulrich and Bassler's New York and Nashville basin faunas are plotted separately to show the similarity in the generic composition of the conodonts on which they based their conclusions. It is readily apparent that the Chattanooga fauna is very similar to the New York Devonian. Furthermore, none of the typical Mississippian genera such as *Pseudopolygnathus*, *Siphonodella*, *Solenodella*, or *Pinacognathus* occur in either fauna. Based on this evidence from generic determinations only, the validity of Ulrich and Bassler's assignment of the Chattanooga fauna to the Mississippian is challenged.

Further reference to Figure 3 indicates a remarkable similarity between the New York Devonian conodonts and those from the Ohio, Huron, and Olentangy shales of the Lake Erie region. The greater part of the New Albany shale of Indiana, Illinois and Kentucky, likewise, contains a fauna of almost identical generic make-up. The Devonian age of the New Albany shale is further supported by the occurrence of definite Devonian brachiopods within 5 feet of the top of the formation.[35] These age relations are also confirmed by the occurrence of the fossil-wood genus *Callixylon* in the New York upper Devonian, Antrim shale of Michigan, New Albany shale of Indiana, and the Chattanooga shale of the northern Nashville basin.[36] Arnold believes the species of the genus *Callixylon* from these

[32] J. H. Swartz, "The Age and Stratigraphy of the Chattanooga Shale in Northeastern Tennessee and Virginia," *Amer. Jour. Sci.*, 5th Ser., Vol. 17 (1929), pp. 431–48.

[33] G. B. Holmes, "Bibliography of the Conodonts and Descriptions of Early Mississippian Forms," *Proc. U. S. Nat. Museum*, Vol. 72, Art. 5 (1928), pp. 1–38.

[34] E. O. Ulrich and R. S. Bassler, "A Classification of the Toothlike Fossil Conodonts with Descriptions of American Devonian and Mississippian Species," *ibid.*, Vol. 68, Art. 12 (1926), pp 1–63.

[35] J. W. Huddle, "Marine Fossils from the Top of the New Albany Shale of Indiana," *Amer. Jour. Sci.*, 5th Ser., Vol. 25 (1933), p. 305.

[36] C. A. Arnold, "The Genus *Callixylon* from the Upper Devonian of Central and Western New York," *Michigan Acad. Sci.*, Vol. 11 (1930), pp. 1–50.

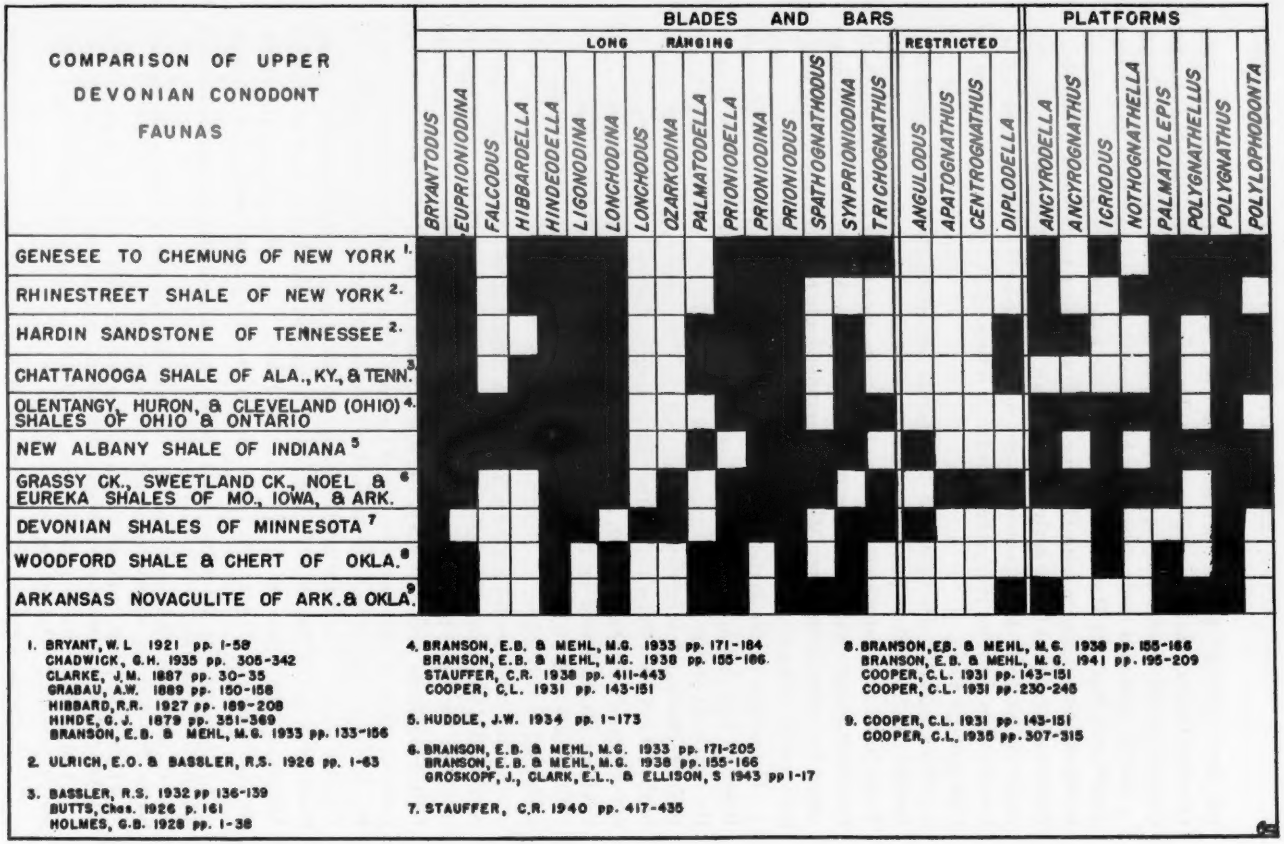
COMPARISON OF UPPER DEVONIAN CONODONT FAUNAS
BLADES AND BARS
LONG RANGING
RESTRICTED
PLATFORMS
BRYANTODUS
EUPRIONIODINA
FALCODUS
HIBBARDELLA
HINDEODELLA
LIGONODINA
LONCHODINA
LONCHODUS
OZARKODINA
PALMATODELLA
PRIONIODELLA
PRIONIODINA
PRIONIODUS
SPATHOGNATHODUS
SYNPRIONIODINA
TRICHOGNATHUS
ANGULODUS
APATOGNATHUS
CENTROGNATHUS
DIPLODELLA
ANCYRODELLA
ANCYROGNATHUS
ICRIODUS
NOTHOGNATHELLA
PALMATOLEPIS
POLYGNATHELLUS
POLYGNATHUS
POLYLOPHODONTA
GENESEE TO CHEMUNG OF NEW YORK 1.
RHINESTREET SHALE OF NEW YORK 2.
HARDIN SANDSTONE OF TENNESSEE 2.
CHATTANOOGA SHALE OF ALA., KY., & TENN. 3.
OLENTANGY, HURON, & CLEVELAND (OHIO) SHALES OF OHIO & ONTARIO 4.
NEW ALBANY SHALE OF INDIANA 5
GRASSY CK., SWEETLAND CK., NOEL & EUREKA SHALES OF MO., IOWA, & ARK. 6
DEVONIAN SHALES OF MINNESOTA 7
WOODFORD SHALE & CHERT OF OKLA. 8
ARKANSAS NOVACULITE OF ARK. & OKLA. 9
1. BRYANT, W. L. 1921 pp. 1-58
CHADWICK, G.H. 1935 pp. 305-342
CLARKE, J.M. 1887 pp. 30-35
GRABAU, A.W. 1889 pp. 150-158
HIBBARD, R.R. 1927 pp. 189-208
HINDE, G.J. 1879 pp. 351-369
BRANSON, E.B. & MEHL, M.G. 1933 pp. 133-156
2. ULRICH, E.O. & BASSLER, R.S. 1926 pp. 1-63
3. BASSLER, R.S. 1932 pp 136-139
BUTTS, Chas. 1926 p. 161
HOLMES, G.B. 1928 pp. 1-38
4. BRANSON, E.B. & MEHL, M.G. 1933 pp. 171-184
BRANSON, E.B. & MEHL, M.G. 1938 pp. 155-166.
STAUFFER, C.R. 1938 pp. 411-443
COOPER, C.L. 1931 pp. 143-151
5. HUDDLE, J.W. 1934 pp. 1-173
6. BRANSON, E.B. & MEHL, M.G. 1933 pp. 171-205
BRANSON, E.B. & MEHL, M.G. 1938 pp. 155-166
GROSKOPF, J., CLARK, E.L., & ELLISON, S 1943 pp 1-17
7. STAUFFER, C.R. 1940 pp. 417-435
8. BRANSON, E.B. & MEHL, M.G. 1938 pp. 155-166
BRANSON, E.B. & MEHL, M.G. 1941 pp. 195-209
COOPER, C.L. 1931 pp. 143-151
COOPER, C.L. 1931 pp. 230-245
9. COOPER, C.L. 1931 pp. 143-151
COOPER, C.L. 1935 pp. 307-315

FIG. 3

related formations are identical and he is convinced the genus is restricted to upper Devonian. It is also important to note that these dark shales, which are correlatives on the basis of conodonts and fossil wood, have abundant resinous spores called "*Sporangites*" (*Tasmanites*). Probably very little significance should be attached to the occurrence of these spores since their stratigraphic range is unknown. However, the spores are easily seen in well cuttings and have been used extensively by petroleum geolosits for recognizing the dark shales now under discussion.

Correlations among beds containing upper Devonian conodonts and fossil wood may be extended further west to include the Grassy Creek shale of northern Missouri, the Sweetland Creek shale of Iowa, the Noel shale of southwestern Missouri, and the Chattanooga shale of Arkansas and northeastern Oklahoma. The conodont faunas from each of these formations are similar to the New York Devonian in generic composition. Some differences do occur, as would be expected in diverse sedimentary environments and from vaiations in methods of collecting. The fossil-wood genus *Callixylon* and the inarticulate brachiopod, *Schizobulus truncatus*, considered to be indicative of Genesee age, are found in the Chattanooga of northern Arkansas.[37] Spores are present in many scattered localities in these related formations but are most abundant in the subsurface of northeastern Oklahoma.

The Woodford formation of Oklahoma and the Arkansas novaculite of Arkansas and southern Oklahoma are a part of the same correlation problem on the basis of conodonts, fossil wood, and spores. Cooper's[38] work on the conodonts from these formations dealt mainly with the specific identification of blades and bars. The generic ranges of these blades and bars are now known to extend through both Mississippian and Devonian and do not appear to be valuable age indicators. However, Cooper described a few of the short-ranging platforms, *Palmatolepis* and *Polygnathellus*, both of which are common to Devonian beds to the east and north. *Icriodus*, another short-ranged Devonian platform, has also been found in the Woodford.[39] Cooper indicated that the Woodford and the Arkansas novaculite conodonts were correlatives with the faunas from the Chattanooga, Ohio, Huron, and Sudbury shales on the east. These correlations appear to be correct but he followed Ulrich and Bassler in assigning each of these faunas

C. A. Arnold, "On *Callixylon newberryi* (Dawson) Elkins et Wieland," *Michigan Univ. Museum Paleontology Contributions*, Vol. 3 (1931), pp. 207–32.

C. A. Arnold, "The So-called Branch Impressions of *Callixylon newberryi* (Dawson) Elkins et Wieland and the Conditions of Preservation," *Jour. Geology*, Vol. 42 (1934), pp. 71–75.

[37] H. D. Miser, "The Devonian System in Arkansas and Oklahoma," *Illinois State Geol. Surv. Bull. 68-A* (1944), pp. 132–38.

[38] C. L. Cooper, "Conodonts from the Arkansas Novaculite, Woodford Formation, Ohio Shales, and Sudbury Shale," *Jour. Paleontology*, Vol. 5 (1931), pp. 143–51.

———, "Conodonts from the Woodford Formation of Oklahoma," *ibid.*, pp. 230–45.

———, "Conodonts from the Upper and Middle Arkansas Novaculite, Mississippian, at Caddo Gap, Arkansas," *ibid.*, Vol. 9 (1935), pp. 307–15.

[39] E. B. Branson and M. G. Mehl, "The Conodont Genus *Icriodus* and Its Stratigraphic Distribution," *Jour. Paleontology*, Vol. 12 (1938), pp. 155–66.

to the Mississippian. In the light of the generic ranges outlined in Figure 3, it appears that these faunas are similar to those in the New York Devonian.

The fossil wood in the Woodford and the Arkansas novaculite has been identified as *Callixyon*. The Woodford species, *Callixylon whiteanum*, is distinct from the *Callixylon newberryi* of New York but the genus indicates a definite Devonian age for the Woodford.[40] Spores are common in the Woodford, particularly in the subsurface. They are also known from the middle member of the Arkansas novaculite at Caddo Gap, Arkansas.

The assignment of a Devonian age to the Chattanooga and the Woodford in Oklahoma meets the greatest opposition from subsurface stratigraphers in the petroleum industry. Both of these formations have a marked angular unconformity at their bases. They overlap beds from the pre-Cambrian to the Bois d'Arc (lower Devonian). Mississippian beds are in most cases directly above the Chattanooga and Woodford. However, a significant unconformity has been demonstrated in the subsurface at the top of the Chattanooga and the Woodford within areas where both were called Mississippian.[41] This unconformity is supported by the important faunal break in conodonts at the top of the Chattanooga in the Bushberg zone. The amount of discordance at the base and at the top of the Chattanooga and Woodford varies with the local area. Degree of discordance is not necessarily a measure of whether the hiatus should represent a system boundary.

Since the conodont faunas and the fossil wood of the Chattanooga and Woodford are clearly like those of the New York upper Devonian, those who believe these beds are Missisippian on structural evidence are forced to assign the Genesee, Naples, and Chemung of New York to the Mississippian. This would meet a tremendous amount of opposing structural and faunal evidence in the Appalachian region. No one has doubted that the faunas from the Genesee, Naples, and Chemung have a closer relationship with the Hamilton (middle Devonian) beds below than with the Pocono (lower Mississippian) above. Certain groups of beds in the upper Chautauquan and Bradfordian groups, well above the Chemung, have been placed by some writers in the Mississippian but their equivalents have not been recognized in the Chattanooga or Woodford. If the Chattanooga and Woodford are placed in the upper Devonian, the only change in thinking that need take place is to assume that greater amounts of discordance exist pre-upper Devonian rather than pre-lower Mississippian.

[40] C. A. Arnold, "*Callixylon whiteanum* sp. nov. from the Woodford Chert of Oklahoma," *Botany Gazette*, Vol. 96 (1931), pp. 180–85.

[41] J. A. Taff, "Description of the Geology of the Atoka Folio," *U. S. Geol. Survey Folio 79* (1902), pp. 1–8.

F. L. Aurin, G. C. Clark, and E. A. Trager, "Notes on the Subsurface Pre-Pennsylvanian Stratigraphy of the North Mid-Continent Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 5 (1921), p. 136.

G. S. Buchanan, "The Distribution and Correlation of the Mississippian of Oklahoma," *ibid.*, Vol. 11 (1927), p. 1311.

Constance Leatherock and N. W. Bass, "Chattanooga Shale in Osage County, Oklahoma, and Adjacent Areas," *ibid.*, Vol. 20 (1936), pp. 91–101.

In the deeper sedimentary basins there are localities where complete sequences of sediments theoretically grade from upper Devonian to lower Mississippian and the gradation may be entirely in the dark shale beds. Possibly this could be true in the subsurface of Oklahoma. However, the outcrops of Woodford have yielded both conodonts and fossil wood of a distinct Devonian character and whatever age assignment is made for the New York Genesee, Naples, and Chemung beds must also be made for the outcropping Woodford.

CONCLUSIONS

For practical purposes conodonts can be divided into four groups as follows: (1) fibrous, (2) simple cones, (3) blades and bars, and (4) platforms. The fibrous and simple cone groups have many genera that serve as excellent guides to the Ordovician. The blade and bar group is mainly long ranging. However, a few genera serve as guides in the Ordovician, Devonian, and Mississippian. The genera in the platform group are the best guides to beds younger than Silurian. Many of these are remarkably restricted.

Stratigraphic leaks and stratigraphic admixtures are terms for mixed faunas that require special interpretation based on a knowledge of faunal sequences and the local field evidence.

The conodonts from the Chattanooga and related beds are shown to be clearly like those in the upper Devonian of New York. The upper Devonian characteristics of these faunas from the Chattanooga are supported by brachiopod and fossil-wood evidence.

CHECK LIST OF CONODONT GENERA

In all, 132 generic names have been introduced in the conodont literature. Eighty-two of these names probably remain valid under present-day concepts. Eighty of these are sketched in Figures 1 and 2. Fifteen names have been definitely placed in synonymy by various revisions in the literature. Twenty-five generic names, those marked with an asterisk (*), are in need of additional research and have not been treated in synonymy by various authors. A suggested treatment is made for each of these names. Ten generic names have very doubtful validity and are marked by a double astrisk (**). This check list may be used as a guide to some future research and it serves as a supplement to the accompanying charts. The list of references given by Branson and Mehl[42] is the basic bibliography to accompany both the check list and the generic range charts.

Acanthodus Furnish, simple cone, lower Ordovician
Acodina Stauffer=*Acontiodus* Pander
Acodus Pander, simple cone, lower Ordovician to middle Silurian
Acontiodus Pander, simple cone, lower and middle Ordovician
Ambolodus Branson and Mehl, fibrous, upper Ordovician
Amorphognathus Branson and Mehl, fibrous, middle and upper Ordovician

[42] E. B. Branson and M. G. Mehl, "Conodonts," in *Index Fossils of North America*, by H. W. Shimer and R. R. Shrock, p. 235. John Wiley and Sons, New York (1944).

Ancyrodella Ulrich and Bassler, platform, middle and upper Devonian
Ancyrognathus Branson and Mehl, platform, middle and upper Devonian
Angulodus Huddle, bar, upper Devonian
Apatagnathus Branson and Mehl, bar, upper Devonian
Archeognathus Cullison, simple cone, middle Ordovician. Closer study may reveal that this genus is not a true conodont but for the present it is being considered valid. It is not sketched on the charts
**Arcugnathus* Cooper, bar, lower Mississippian. This is probably a fragment of *Hindeodella* Ulrich and Bassler
Bactrognathus Branson and Mehl, blade, lower and middle Mississippian
**Barbarodina* Stauffer, bar, middle Ordovocian. This probably belongs to *Cordylodus* Pander
Belodus Pander, bar, lower to upper Ordovician
***Bransonella* Harlton, lower Pennsylvanian. This is probably not a true conodont
Bryantodina Stauffer, blade, middle Ordovician
Bryantodus Ulrich and Bassler, blade, upper Devonian to middle Mississippian
Cardiodella Branson and Mehl, fibrous, middle Ordovician.
Cardiodus Branson and Mehl=*Cardiodella* Branson and Mehl.
Cavusgnathus Harris and Hollingsworth, platform, upper Mississippian to Permian
Centrodus Pander=*Lonchodus* Pander
Centrognathodus Branson and Mehl, bar, upper Devonian
Centrognathus Branson and Mehl=*Centrognathodus* Branson and Mehl
**Cervicornoides* Stauffer, bar, middle Devonian. This is a specialized type of *Hindeodella* Ulrich and Bassler
Chirognathus Branson and Mehl, fibrous, middle Ordovician
Clavohamulus Furnish, simple cone, lower Ordovician
Coleodus Branson and Mehl, fibrous, middle Ordovician
Cordylodus Pander, bar, lower to upper Ordovician
***Cornuramia* Smith, Ordovician. The exact relationships of this form are very doubtful
**Ctenognathus* Pander, Silurian to Pennsylvanian. This genus in part belongs to *Ozarkodina* Branson and Mehl
Curtognathus Branson and Mehl, fibrous, middle Ordovician
Cyrtoniodus Stauffer, bar, middle Ordovician
Dichognathus Branson and Mehl, blade, middle Ordovician.
**Dinodus* Cooper, blade, lower Mississippian. This probably belongs to *Falcodus* Huddle
Diplodella Ulrich and Bassler, bar, upper Devonian
Distacodus Hinde, simple cone, lower Ordovician to middle Silurian
Doliognathus Branson and Mehl, platform, lower and middle Mississippian
Drepanodus Pander, simple cone, lower to upper Ordovician
**Dryphenotus* Cooper, platform, lower Mississippian. This is a specialized form of *Gnathodus* Pander
**Elictognathus* Cooper, platform, lower Mississippian. This is a specialized form of *Solenodella* Branson and Mehl
**Elsonella* Youngquist, blade, upper Devonian, This probably belongs to *Synprioniodina* Ulrich and Bassler or to *Palmatodella* Ulrich and Bassler
Erismodus Branson and Mehl, fibrous, middle Ordovician
Euprioniodina Ulrich and Bassler, bar, upper Ordovician to middle Pennsylvanian
Falcodus Huddle, blade, upper Devonian to middle Mississippian
Gnathodus Pander, platform, lower Mississippian to middle Pennsylvanian
Gondolella Stauffer and Plummer, platform, lower Pennsylvanian to Permian
**Gyrocanthus* Stauffer, bar, middle Ordovician and Devonian. This probably belongs to *Oulodus* Branson and Mehl
**Hamulosodina* Cooper, bar, upper Devonian. This probably belongs to *Hindeodella* Ulrich and Bassler
Heterognathus Stauffer=*Provognathus* Stauffer
Hibbardella Ulrich and Bassler, bar, upper Devonian to upper Pennsylvanian
Hindeodella Ulrich and Bassler, bar, upper Ordovician to Permian
**Hindeodelloides* Huddle, bar, upper Devonian and lower Mississippian. This probably belongs to *Hindeodella* Ulrich and Bassler
Icriodus Branson and Mehl, platform, middle and upper Devonian
Idiognathodus Gunnell, platform, lower to upper Pennsylvanian
Idiognathoides Harris and Hollingsworth=*Polygnathodella* Harlton
Idioprioniodus Gunnell=in part *Ligonodina* Ulrich and Bassler and in part *Trichognathus* Branson and Mehl
***Lepodus* Branson and Mehl, middle Ordovician. This may not be a true conodont
Leptochirognathus Branson and Mehl, fibrous, middle Ordovician

*******Lewistownella* Scott, Mississippian. This is an assemblage that includes ***Hindeodella*** Ulrich and Bassler, *Prioniodus* Pander, ***Subbryantodus*** Branson and Mehl, and *Cavusgnathus* Harris and Hollingsworth

Ligonodina Ulrich and Bassler, bar, middle Silurian to Permian

**Ligonodinoides* Stauffer, bar, middle and upper Devonian. In part this belongs to *Ozarkodina* Branson and Mehl and in part it belongs to *Prioniodus* Pander

***Lochriea* Scott, Mississippian. This is an assemblage that includes *Hindeodella* Ulrich and Bassler, *Spathognathodus* Branson and Mehl, *Prioniodus* Pander, and *Prioniodella* Ulrich and Bassler

Lonchodina Ulrich and Bassler, bar, middle Silurian to Permian

Lonchodus Pander, bar, middle Ordovician to middle Pennsylvanian

Loxodus Furnish, bar, lower Ordovician

Loxognathus Graves and Ellison = *Dichognathus* Branson and Mehl

Machairodia Smith = *Distacodus* Hinde

Machairodus Pander = *Distacodus* Hinde

**Macropolygnathus* Cooper, platform, lower Mississippian. This belongs to *Polygnathus* (Hinde) Bryant

**Mehlina* Youngquist, blade, upper Devonian. This belongs to *Spathognathodus* Branson and Mehl

Metalonchodina Branson and Mehl, bar, upper Mississippian to Permian

**Metaprioniodus* Huddle, bar, upper Devonian and lower Mississippian. This probably belongs to *Hindeodella* Ulrich and Bassler

Microcoleodus Branson and Mehl, bar, middle Ordovician. This may be a fibrous form

Multioistodus Cullison, fibrous, middle Ordovician

Neocoleodus Branson and Mehl, fibrous, middle Ordovician

**Neocordylodus* Cooper, bar, lower Mississippian. This includes specimens of *Ligonodina* Ulrich and Bassler, *Trichognathus* Branson and Mehl, and *Lonchodina* Ulrich and Bassler

**Nodognathus* Cooper, platform, lower Mississippian. This probably is an immature *Pseudopolygnathus* Branson and Mehl

Nothognathella Branson and Mehl, platform, upper Devonian

Oistodus Pander, simple cone, lower to upper Ordovician

***Oligodus* Cooper, lower Mississippian. This has very questionable affinities

Oulodus Branson and Mehl, bar, middle Ordovician

Ozarkodina Branson and Mehl, blade, middle Ordovician to Permian

***Pachysomia* Smith, Ordovician. This has very doubtful relationships

Palmatodella Ulrich and Bassler, bar, upper Devonian and lower Mississippian

Palmatolepis Ulrich and Bassler, platform, upper Devonian

Paltodus Pander, simple cone, lower Ordovician to middle Silurian

**Pandorina* Stauffer, blade, middle Devonian. This probably belongs to *Spathognathodus* Branson and Mehl

**Panderodella* Ulrich and Bassler, upper Devonian. This probably is a broken fragment of *Palmatolepis* Ulrich and Bassler

Phragmodus Branson and Mehl, bar, middle and upper Ordovician

Pinacodus Branson and Mehl = *Pinacognathus* Branson and Mehl

Pinacognathus Branson and Mehl, blade, lower Mississippian

**Plectodina* Stauffer, blade, middle Ordovician and middle Devonian. This probably belongs to *Ozarkodina* Branson and Mehl

Plectospathodus Branson and Mehl, blade, middle Silurian

Polycaulodus Branson and Mehl, fibrous, middle Ordovician

Polygnathella Ulrich and Bassler, platform, middle Silurian to upper Devonian

Polygnathoides Branson and Mehl, platform, middle Silurian

Polygnathus (Hinde) Bryant, platform, upper Devonian to middle Mississippian

Polygnathodella Harlton, platform, lower Pennsylvanian

Polylophodonta Branson and Mehl, platform, upper Devonian

Polyplacognathus Stauffer = *Amorphognathus* Branson and Mehl

Prioniodella Ulrich and Bassler, bar, upper Devonian to lower Mississippian

Prioniodina Ulrich and Bassler, blade and bar, upper Devonian to upper Pennsylvanian

Prioniodus Pander, bar, lower Ordovician to Permian

***Prioniognathus* Pander, Ordovician and Silurian. This has very doubtful relationships

Provognathus Stauffer, bar, middle Ordovician. This is not sketched on the charts

Pseudopolygnathus Branson and Mehl, platform, lower Mississippian

Pteroconus Branson and Mehl, bar, middle to upper Ordovician. This form may be fibrous

Scaliognathus Branson and Mehl, platform, lower Mississippian

***Scolopodella* Stauffer and Plummer, middle Pennsylvanian. This has very doubtful relationships

Scolopodus Pander, simple cone, lower Ordovician

***Scyphiodus* Stauffer, middle Ordovician. This is a very doubtful genus

Siphonodella Branson and Mehl, platform, lower Mississippian
Siphonognathus Branson and Mehl=*Siphonodella* Branson and Mehl
Solenodella Branson and Mehl, platform, lower Mississippian
Solenognathus Branson and Mehl=*Solenodella* Branson and Mehl
Spathodus Branson and Mehl=*Spathognathodus* Branson and Mehl
Spathognathodus Branson and Mehl, blade, middle Silurian to Permian
Staurognathus Branson and Mehl, platform, lower Mississippian
Stereoconus Branson and Mehl, fibrous, lower and middle Ordovician
Streptognathodus Stauffer and Plummer, platform, lower Pennsylvanian to Permian
Subbryantodus Branson and Mehl, blade, lower Mississippian
**Subcordylodus* Stauffer, bar, middle Ordovician. This probably belongs to *Cordylodus* Pander
**Subprioniodus* Smith, bar, Ordovician. This probably belongs to *Prioniodus* Pander
Synprioniodina Ulrich and Bassler, blade, upper Devonian to Permian
Taphrognathus Branson and Mehl, platform, middle Mississippian
**Telumodina* Cooper, bar, upper Devonian. This probably belongs to *Euprioniodina* Ulrich and Bassler
**Tortonoides* Stauffer, blade, middle Ordovician. This probably belongs in part to *Bryantodina* Stauffer and in part to *Ozarkodina* Branson and Mehl
Trichognathus Branson and Mehl, bar, middle Ordovician to Permian
Trucherognathus Branson and Mehl, fibrous, middle Ordovician
Ulrichodina Furnish, simple cone, lower Ordovician
**Valentia* Smith, bar, Ordovician. This probably belongs to *Lonchodus* Pander

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GEOLOGICAL NOTES

OUTLINE FOR REGIONAL CLASSIFICATION OF OIL POSSIBILITIES[1]

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Classifications in map form drawn up to show the oil possibilities of countries or continental areas vary widely in the values given to comparable regions. The following discussion and outline are prepared for the purpose of giving such classifications some degree of uniformity.

For these classifications which are based mainly on published geological data or information gained in reconnaissance surveys, the following five classes are considered to be sufficient: (1) proved, (2) probably productive, (3) possibly productive, (4) unfavorable, and (5) barren territory.

GENERALIZATIONS ON WHICH OUTLINE IS BASED

SOURCE ROCKS AND OIL SHOWINGS

A series of marine sedimentary rocks that include calcareous and fine-grained detrital sediments is likely to contain source material. Further speculation about the oil content of a sedimentary series must depend chiefly on surface or underground showings of oil. But where the strata are only gently folded, the fact that no indications of oil appear at the surface is no evidence that the underlying formations are not oil-bearing. If, however, the strata are strongly folded and most of the potential oil sands are exposed at many places throughout the basin without any indications of oil, the formations are probably not petroliferous. This is thought to be especially true if they are Tertiary in age. On the other hand, slight surface indications associated with igneous intrusions, or occurring in highly folded and faulted strata, need not be given much weight in appraising the oil prospects of an area. Gas showings, even those containing a small percentage of ethane, are not necessarily an indication of oil. Only where active seeps appear in conjunction with other favorable factors are surface indications to be regarded as strong evidence of oil possibilities.

POROSITY OF FORMATIONS

In general, the porosity of formations decreases in proportion to their age, former depth of burial, and the number of orogenies that they have undergone. As a general rule, it may be assumed that reservoir rocks are present in any unmetamorphosed Tertiary or Mesozoic sedimentary series that does not consist entirely of clays and shales. Fine-grained brittle sediments such as limestone and marl in these and older formations may also be viewed as potential reservoir

[1] Manuscript received, October 18, 1945.

[2] Consulting geologist.

rocks if they have been folded sufficiently to develop a system of joints and fissures. It is inadvisable to assume that sandstones in Paleozoic formations have much porosity unless they occupy a relatively shallow basin or have had an uneventful geological history.

In the absence of exact data afforded by drill holes on the porosity and permeability of strata about which there may be some uncertainty, one may rely to some extent on the information furnished by springs. If springs appear at the outcrop of certain sandstones it is good evidence that these sandstones have an appreciable porosity. If warm fresh-water springs, that is, those with temperatures slightly in excess of the mean annual air temperature, are found in basins that have had no recent volcanic activity and issue at the outcrop of sandstones or limestones, these rocks are probably porous over wide areas.

The carbon ratios of any coals that may be present and have been analyzed will furnish information as to the stage reached in the incipient metamorphism of the coal-bearing formations and indicate to what extent the associated sandstones may have become indurated and tight-grained. It is doubtful, however, whether carbon ratios will furnish data on the possibility of limestones serving as reservoir rocks, for highly altered limestones that have been fissured may serve in that capacity. At any rate, it should be remembered that the stage reached in the induration of any series, as indicated by the carbon ratios of its coals, will differ materially from that of formations higher or lower in the stratigraphic section. This difference may become especially marked if unconformities representing long breaks in geologic time are present.

EFFECT OF IGNEOUS INTRUSIONS

The presence in a sedimentary basin of igneous intrusions, such as dikes and sills or volcanic flows and ejected material or bordering volcanic ranges, probably has had little or no effect on the regional alteration of the sediments except to the extent that their overburden has been increased by igneous material. Where volcanic outbursts have occurred during the deposition of the sediments it is possible that the porosity of sandstones has been reduced by the addition of volcanic ash. But apart from these considerations, volcanic activity does not lessen the oil possibilities of a basin. In fact, pyroclastic material occurs so commonly in oil-bearing formations as to suggest that it may have played some role in the generation of petroleum.

COVER ROCK

The matter of cover rock can be ignored in a normal sequence of sedimentary strata where the potential oil sands are interbedded with fine-grained sediments. It becomes important when the sedimentary series consists chiefly of porous beds or where massive limestones, marls, and sandstones have been sharply folded. The jointing that accompanies the deformation of such rocks furnishes a means for the escape of hydrocarbons, unless the massive and brittle beds have a cover of shales, clays, or other plastic sediments.

STRUCTURAL AND STRATIGRAPHIC TRAPS

In preliminary classifications, such as those under consideration, the matter of accumulation must be viewed chiefly from the standpoint of structural traps. Except for unconformable overlaps, drilling operations are usually necessary in order to form reliable opinions about the existence of stratigraphic traps. At any rate, it may be assumed that in a basin possessing well defined anticlines and domes most of the commercial fields are confined to those structures.

The usual ideas about the role that structure plays in accumulation are here accepted and need not be enumerated. It may be pointed out, however, that in basins with a relief and structure favorable to the circulation of artesian water, basinward structures are given a higher rating than those that flank bordering uplifts. The idea that active ground-water circulation has been an important factor in the depletion of former accumulations of oil appears sound, and there is no reason for abandoning it because it may have been overstressed in the past. It is evident, also, that the chances for accumulation become progressively less as deformation increases beyond a certain stage. It is also assumed that the oil prospects of strongly folded strata decrease as the age of the formation increases.

RELATIVE OIL POSSIBILITIES OF ROCKS OF DIFFERENT AGES

In general it may be stated that beginning with the Miocene the oil possibilities of a sedimentary series are inversely proportional to its age. Tertiary rocks offer better prospects than Mesozoic rocks, and Mesozoic rocks have better prospects than Paleozoic rocks. The differences may be attributed in part to the lower porosity of the older rocks and to the fact that in the course of geologic time accumulations of oil are likely to be gradually depleted by seepages. This being so, it is to be expected that important accumulations in Paleozoic formations will be found only in slightly folded basins, or in strongly folded basins in which the potential oil sands do not reach the surface over fairly large areas.

APPRAISALS NECESSARILY TENTATIVE

The foregoing generalizations are based on observation, theory, and inference. The factual and theoretical data that can be offered to support these generalizations have been omitted, for to do this adequately would require a lengthy treatise that would go beyond the purpose of this paper, which is to present criteria for the rough appraisals of regions about which little geological information is available.

OUTLINE

1. PROVED TERRITORY: Productive areas and undeveloped parts of proved fields
2. PROBABLY PRODUCTIVE TERRITORY: Fairly certain to yield commercial pools of oil
   - A. Untested structures in productive districts that are being held in reserve or that await drilling
   - B. Unexplored parts of a productive oil province in which the geologic conditions appear as favorable for the accumulation of oil, as in productive parts of the province
   - C. Undeveloped basins or coastal plains underlain by a thick marine sedimentary series possessing favorable structure, lithology, and surface indications of oil
3. POSSIBLY PRODUCTIVE TERRITORY: Offers sufficient prospects to warrant exploration but does not justify immediate drilling

A. Untested parts of oil provinces which offer some promise of further discoveries
Undeveloped basins occupied by marine sedimentary rocks that show a slight monoclinal dip with possibilities of accumulation due to slumping over buried ridges, transgressive overlaps, or the offsetting of strata by faults
Basins occupied by a thick marine sedimentary series with surface seeps along the margin of the basin and in highly disturbed zones, such as those bordering diapiric masses of salt or other plastic deposits. In these basins the failure of exploratory tests to find commercial pools may be due to the fact that most drilling has been confined to the seepage areas, where structural conditions are not so favorable for the accumulation of oil as in less disturbed parts of the basin

B. Basins having a considerable thickness of marine sedimentary rocks with attractive structures, in which the failure of a few well located tests may be attributed to the local absence of reservoir rocks or to water flushing
Areas with complex structure that possess some of the earmarks of potential oil territory but in which the failure to obtain commercial production to date may be due to the fact that the oil is confined to narrow belts that have been missed by the drill

C. Foothill provinces surfaced by a highly disturbed series of plastic or incompetent beds that overlie more massive sedimentary formations that may not be closely folded
Mountain ranges with overthrust sheets that cover extensive areas of younger sedimentary strata

4. UNFAVORABLE TERRITORY: Offers little prospect for development of commercial oil fields
   A. Areas occupied by practically horizontal sedimentary strata in which no porous beds have been encountered
   B. Areas underlain only by non-marine sedimentary strata. May possess favorable structure or slight surface indications of oil
   C. Tightly folded areas in which practically all the strata are vertical or overturned
5. BARREN TERRITORY: Possesses no oil prospects whatsoever
   A. Strongly folded mountain ranges with igneous or metamorphic basement rocks exposed in the crests of arches or in upthrust belts
   B. Small sedimentary outliers existing as perched erosional remnants or a thin sedimentary series in synclinal basins or downfaulted belts, in regions otherwise occupied by igneous or metamorphic rocks
   C. Areas where crystalline or metamorphic basement rocks are overlain by only a thin veneer of sedimentary strata
   D. Areas occupied solely by igneous or metamorphic rocks

PREPARATION AND USE OF CLASSIFICATIONS

It is obvious that classifications should be based on all available geologic information pertaining to the oil prospects of the countries under investigation. This information for the most part will probably be derived from published geologic literature, which may be voluminous inasmuch as most foreign countries have geological surveys or their equivalents and are covered wholly or in part by geologic maps. Even the more remote and unprogressive countries have been visited by explorers in search of scientific knowledge or adventure. The accounts of their travels usually yield sufficient information to make it possible to recognize whether or not the explored region offers any promise of oil. Where reconnaissance geological mapping has been done it may be possible roughly to outline the promising and unpromising regions and in some instances the unpromising region may be subdivided into barren and unfavorable territory and the promising into possibly and probably productive territory, but to make the latter distinction requires detailed geologic information, and if such is not available it is inadvisable to go beyond classifying the promising territory as possibly productive.

In the more detailed classification it may be practicable to indicate the relative prospects of specified areas within a class by giving them A, B, and C sub-

headings, as has been done in the foregoing outline. It is not intended, however, that the positions given to the areas listed in the outline should be accepted for their exact rank in any classification in which they appear, for modifying factors may enter to increase or lessen their prospective value in a particular area. The outline, therefore, is not to be considered as a form to be filled in but as a guide in drawing up classifications which will require considerable judgment on the part of the geologist making them. But without some such guide or basis of control, classifications by different geologists, or by an individual geologist, of widely separated areas may not indicate the true comparative values of each area.

As a rule, geologists who plan foreign exploratory programs do not ignore any pertinent information that can be acquired from the geologic literature. In fact, exploratory work in its initial stages is usually based on published data. But it is equally important that the geologist who is in charge of field work should acquire all the information that is available on the geology of the region that he is to explore. The belief that a geologist should begin field work in a new region unhampered by previously acquired information and possible misconceptions does not give much credit to his ability as an exploratory geologist. Moreover, if he arrives in a foreign country without a considerable knowledge of its geology and has no well defined plans he will probably lack the sense of assurance and drive necessary to do his job with any dispatch and may also have his time wasted in investigating areas brought to his attention by persons with special interests to serve.

In conclusion, the writer wishes to express appreciation for the advice and criticisms that he has received from various geologists of world-wide experience to whom he has submitted this paper in manuscript form.

SUGGESTION FOR NAMING MULTIPLE SANDS[1]

ROY E. DICKERSON[2] AND H. W. STRALEY, III[3]

Naming multiple sands in some of the great producing oil fields of California and South America presents a problem of some difficulty. Some sands, both dry and productive, split; others coalesce to form a single stratum. Additional sands may be discovered as drilling progresses toward the periphery of a field, interfingering with earlier named formations, overlying the youngest stratum in the middle, or at a depth in excess of that attained by the wells from which the sands were named.

Following the normal stratigraphic procedure may be inadvisable. The mapping may be incomplete; correlation may be in doubt; type sections may be inadequate.

[1] Manuscript received, November 24, 1945.

[2] Deceased.

[3] Consultant in exploration and valuation of mining and oil properties, Princeton, West Virginia.

Any substitute scheme must be flexible and adjustable to development. Names should be selected according to some readily remembered system. Numbers and simple letters become confusing and do not afford the necessary flexibility.

One object in selecting names is to give marked individuality. To attain this, the names of stratigraphically adjacent formations should be quite dissimilar, but

TABLE I

Two Methods of Naming Sands in Hypothetical Field

Depth (Feet)	*Bentley*		*Language*	
	Original	*Additions*	*Original*	*Additions*
2720–2760		Adcat		Abner
3050–3120		Adpol		Alvan
3150–3170		Benzo		Brian
3240–3260	Ceart		Cyril	
3350–3380	Dobil		Denis	
		Eklon		Elias Ellim
3500–3570	Ekort	Ekboy	Ellis	Edwin or Ellip
		Ekpor		Elmer Ellit
3600–3610	Fetam		Felix	
2650–3680	Gezip		Giles	
		Hafil		Hazel
3750–3810	Herba		Hiram	
		Himid		Hulda
3850–3880	Icord		Isaac	
		Jelpa		James
4010–4030	Jiloy		Jesse	
4120–4140	Kofua		Karen	
4190–4220	Lekad		Lucai	
4270–4280	Miboy		Mabel	
4340–4360	Nergo		Nancy	
4420–4460	Octum		Olive	
4510–4520	Pelto		Polly	
4650–4710	Ritza		Ralph	
4760–4770	Serip		Susan	
4830–4860	Tofab		Tommy	
4920–4930	Ulfus		Ulric	
4970–4980	Venta		Viola	
5010–5021	Wifem		Wilma	
5060–5080		Yesso		Yemen
5150–5180		Zinno		Zebon
6010–6050		Zoyod		Zebra

short and easily pronouncable. Five-letter words, such as are used in cable codes, fit the requirements admirably.

Two schemes for naming sands in alphabetical order are presented. The first is based on the Bentley telegraphic code; the second on words chosen from the dictionary.

An example, using both schemes, may serve to illustrate (Table I). Hypothetically in one field there are 20 sands with economic possibilities, as shown by electrical logs of five wells spaced over a considerable area and between 3200 and 5000 feet deep. At some places, a certain sand is 70 feet thick (3500–3570 feet);

at others, it divides into three separate sands with ten feet of shale between them. Likewise, as development progressed, higher sands at 2720–2760, 3050–3120, and 3150–3170 feet were found. Deeper drilling disclosed sands between 5060 and 5080, 5150 and 5180, and 6010, and 6050 feet.

To name the sands according to the first scheme, select names from the middle part of each code letter. To provide for the contingency of peripheral sands or deeper drilling, a specified number of letters should be reserved at the beginning and end of the alphabet. Reserving A, B, Y, and Z for these purposes and recalling that the Bentley code has omitted Q and X, there are 20 letters available from which to assign names to the 20 sands.

The names chosen appear in the column headed Bentley (Table I). They begin with CEART for the topmost sand between 3240 and 3260 feet and end with WIFEM, the bottommost between 5010 and 5021 feet.

Sands not found in the first wells must be fitted into the scheme. The first two letters of the alphabet were reserved for formations above CEART; the three sands later discovered in this part of the section are ADCAT, ADPOL, and BENZO. Similarly, lower sands encountered in deeper drilling are YESSO, ZINNO, and ZOYAD. To name sands found by subsequent drilling between any two previously encountered and designated formations, one uses the ordinary vowel order. Thus, a sand between GEZIP and HERBA, in the outer limit of the field, can be designated HAFIL; one between HERBA and ICORD, as HIMID; and one between ICORD and JILOY, as JELPA. The EKORT sand (3500–3570 feet) splits into three members, ELKON, EKBOY, and EKPOR, all of which have the same second vowel (o) to designate the split relationship.

Bentley code words usually are not language words. They lack warmth and association which render them difficult to retain. Five-letter language words, chosen from the names in the back of *Webster's Practical Dictionary*, remove that difficulty and constitute the basis for the second suggestion.

Later discoveries may be handled as they were under the Bentley scheme (Table I). The upper sands are ABNER, ALVAN, and BRIAN; the lower, YEMEN, ZEBON, and ZEBRA. The interspaced sands, HAZEL, HULDA and JAMES, can be named readily. It is difficult, however, to name systematically ELLIS' cousins: ELIAS, EDWIN, and ELMER, without recourse to a code device, such as ELLIM, ELLIP, and ELLIT.

For practical field usage, especially in a single field, the writers prefer language to code words. Not only drillers and geophysicists, but even stratigraphers, find SUSAN, TOMMY, and VIOLA easier to remember than SERIP, TOFAB, and VENTA. Wherever it is necessary to break over into the code scheme, it may be done without confusion, as above with ELLIM, ELLIP, and ELLIT, for ELIAS, EDWIN, and ELMER. Perhaps, the break from language words to code words may be useful in calling attention to a peculiarity in the section.

DEVONIAN(?) PRODUCING ZONE, TXL POOL, ECTOR COUNTY, TEXAS[1]

MAX DAVID[2]
Midland, Texas

The Devonian(?) chert producing zone in the recently discovered TXL pool, Ector County, Texas, is probably one of the most interesting types of reservoir rock discovered. Credit for the discovery goes to the Shell Oil Company, Inc., and the Cities Service Oil Company. Silurian (?) and Ellenburger production has also been developed in TXL. There had been twenty-four Devonian and two Ellenburger wells completed, and there were approximately thirty-five drilling operations on November 1, 1945.

Permian rocks rest unconformably on truncated pre-Permian beds on the TXL anticline; the two sets of rocks are separated by a major unconformity expressed in the subsurface as a detrital zone. Structurally low wells have encountered Mississippian (?) shale (Woodford) immediately below the unconformity; higher wells encounter the Devonian(?) chert reservoir; still higher wells miss the chert reservoir and go into stratigraphically older Devonian (?) rocks. Devonian (?) production is confined to date to the west flank of the structure. Over-all productive thickness varies; the maximum over-all productive thickness at one location was 160 feet. The gravity of the Devonian (?) crude is 38.8° API at 60°F. Present information indicates a gas-drive type of reservoir energy. A gas cap has not been found and is not anticipated since the crude is undersaturated by 600 pounds per square inch.

The Devonian (?) pay is very hard, white to buff, opaque, very fine-grained, sedimentary, siliceous rock. It would be classified as novaculite, according to King.[3] It closely resembles the exposed Caballos novaculite of the Marathon region, which he describes. Variable amounts of very finely porous, oil-stained siliceous material resembling tripoli are commonly associated with the novaculite. Due to the extreme hardness of the reservoir rock (approximately 4 weeks are required to drill the productive section on the average well), practically no coring has been attempted. Consequently, there is no measurable knowledge of the void space. High permeability conditions are known to be present from production and drill-stem test records. Flows as high as 140 barrels of oil per hour through $\frac{5}{8}$-inch bottom-hole choke have been recorded. Such high permeability suggests a fracture to cavernous type of void space. The highest permeability is present in those locations in which the siliceous material is principally novaculite and in contact with the major unconformity. Less porosity and permeability is found at those locations where the Devonian (?) is overlain by Mississippian (?) shale.

[1] Manuscript received, November 13, 1945.

[2] Consulting geologist.

[3] Philip B. King, "Geology of the Marathon Region, Texas," *U.S. Geol. Survey Prof. Paper 187.*

A dry hole on the west side of the pool thoroughly tested the Devonian (?) producing equivalent without developing any free fluids; indicating porosity and permeability is poor to absent at low structural positions. It is also noted in the structurally low wells, that the Devonian (?) novaculite section has a marked increase in the percentage of dolomitic limestone, whereas, almost no carbonates are present in the producing zone in higher wells.

The very rigid nature of the reservoir rock strongly suggests void space was initiated by fracturing and shattering at the time the anticline was folded—probably at the end of Pennsylvanian time. Later exposure of the Devonian (?) prior to Permian deposition probably resulted in the solution of carbonates within the siliceous matrix. Such hypothesis precludes any possibility of the oil being indigenous to the rock in which it is now found. It further implies the oil is younger than the reservoir rock.

NATURAL RESOURCES SECTION IN JAPAN AND KOREA[1]

THOMAS A. HENDRICKS[2]
Tokyo, Japan

The Supreme Commander for the Allied Powers in Tokyo has established a Natural Resources Section directly under the Chief of Staff to treat with all questions pertaining to Agriculture, Forestry, Fisheries, and Mining and Geology in Japan and Korea. Lt. Col. HUBERT G. SCHENCK, professor of geology at Stanford University (on leave), is in charge of the Section, which has as its primary mission the making of a complete study and appraisal of the resources, reserves, and potentialities of Japan and Korea. In addition, the Section initiates action to stimulate and maintain production of natural resources in accordance with the needs of the Occupation Forces and a limited Japanese economy as prescribed by the Potsdam Conference. The personnel consists of Army officers and enlisted men who are qualified technical men in the respective fields and civilian experts mostly assigned through the Military Geology Unit of the U. S. Geological Survey. THOMAS A. HENDRICKS, of the Geological Survey, is Chief of Mining and Geology Division and Major DANFORTH C. WASHBURN, formerly of The Texas Company, is assistant chief. Major JOSEPH NEELY, formerly with the Magnolia Petroleum Company, is head of the Fuels branch of Mining and Geology, which treats with petroleum and coal. In his petroleum work he is assisted by DAVID J. CERKEL, JR., and RAYMOND M. BECKER, of the Conservation Branch of the Geological Survey, LEOPOLD W. STACH, of the Australasian Petroleum Company, Lt. A. A. NICHOLS, who was with the Sun Oil Company before the war, and Master Sergeant LESH FORREST, of the Richfield Oil Company in California. Major ROBERT M. BEATTY, formerly with DeGolyer and McNaughton, is chief of the Library and Production Division of the Section, and is assisted by Capt. HAROLD H. HAWKINS, who left the National Park Service for the Army. Major ELMER W. ELLSWORTH, consulting geologist from Centralia, Illinois, is technical supervisor of the Section. The work of the Specialists involves field and office studies on which are based reports for army use, and, after proper clearance, papers by the individual authors should be available for publication.

[1] Manuscript received, January 5, 1946.

[2] U. S. Geological Survey.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS •
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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

REPORT ON EXPLORATION FOR OIL IN BRITISH GUIANA, BY H. G. KUGLER ET AL.

REVIEW BY H. D. HEDBERG[1]
Caracas, Venezuela

"Report on Exploration for Oil in British Guiana," by H. G. Kugler, S. C. Mackenzie, R. M. Stainforth, J. C. Griffiths, and G. R. Brotherhood. *Geological Survey of British Guiana Bulletin 20, 1942* (1944), Georgetown, Demerara. 78 pp., graphic log, seismic contour map, and 6 other enclosures. Price, $1.00.

The first deep well for oil in British Guiana was spudded in, on August 14, 1941, by the Central Mining and Investment Corporation and the Trinidad Leaseholds, Ltd., in the coastal area of the northeastern part of this country between the Berbice and Courantyne rivers. This well started in Demerara clay—a brackish-water to marine deposit of "sub-Recent" age. At a depth of about 100 feet, it entered the dominantly nonmarine "littoral-deltaic" Berbice formation of Pleistocene-Pliocene age, consisting of conglomerates, sands, and clays with some lignites, which continued to 6310 feet. At this depth, the well encountered weathered igneous basement rock and was finally stopped in relatively fresh quartz-feldspar porphyry at 6456 feet, on November 30, 1941. The only indication of petroleum was the presence of drops of heavy black oil in the drilling mud on reaching a depth of 6074 feet. No tests were made and the hole was abandoned and the concession dropped.

The story of this well (Rose Hall well) is told in detail in a private report which, through permission of the Central Mining and Investment Corporation, was made accessible by the British Guiana Government in the publication under review.

For years the coastal belt of British Guiana has been considered as a possibly petroliferous area, the critical factors being the thickness of sediments above the igneous-metamorphic basement rocks and the possible presence of Cretaceous or Tertiary beds of shore-line facies beneath the unconsolidated surface deposits. The possibility of conditions comparable with those in the oil fields of the northern flank of the Guayana shield in Eastern Venezuela has been intriguing. Surface geology and the study of water-well sections had already shown the uppermost part of the sedimentary section in the coastal area to consist entirely of Quaternary sediments overlapping southward on basement rock. While the distribution of these surface and near-surface sediments indicated the presence of a sedimentary embayment in the Berbice area, they could give little indication of the depth of underlying strata or their age, structure, and character. Recourse was therefore had to a combined reflection and refraction seismic survey, which showed a slightly undulating northward-dipping basement surface and a thickness of sedimentary cover as great as 7300 feet. An 11,000 feet-per-second velocity bed was indicated at a distance of 1000–1250 feet above the basement, which suggested the possibility of Cretaceous or older Tertiary sediments in the lower part of the section. On the strength of these data, the Rose Hall test was drilled, the chosen location being on a basinward-projecting seismic nose with a slight closure. Basement depth was predicted at 6250–6300 feet by the seismograph and the deeply weathered top of the basement was actually found between 6310 and 6410 feet. The high-velocity bed was correlated with a conglomerate at 5435–5525 feet, but was concluded to be within the Berbice formation.

[1] Mene Grande Oil Company. Review received, November 19, 1945.

The one showing of oil in the well—little drops of heavy black oil on the ditch at 6074 feet—is of a rather dubious character and is considered of little significance. Unfortunately, no electrical log is available at this particular point in the section. The widely known occurrences of "drops of inspissated oil or lumps of asphalt" along the British Guiana coast are discussed by Kugler, who particularly considers the idea that they, as well as the showing in the Rose Hall well, may have been derived from submarine seepages on the north slope of the Guiana shield. In this connection, he mentions the possibility of finding accumulations of oil off the northern shore line of British Guiana, even though prospects on the mainland may be condemned.

Electrical surveys are available for the intervals 431–4401 feet and 4692–5415 feet. Interpretation is complicated by the varying balance between the salinity of the drilling mud and that of the formation water. An electrical dip-meter survey shows dips of 5–10° in a general northerly direction.

Of particular interest to students of sedimentation and sedimentary rocks are the detailed descriptions of the lithology, petrography, mineralogy, and paleontology of samples from the well section by Kugler and Stainforth (pp. 32–47) and Griffiths (pp. 60–73). The sediments are largely considered to represent first-cycle deposits derived from a granite and metamorphic complex covered by a deep layer of residual soil and laid down in brackish water near a shore line. Diagenesis and lithification are still in the early stages. Mechanical analyses stress the absence of silt and the dominance of two grades—coarse detritus down to fine sand, representing the chemically resistant residue of igneous and metamorphic rocks, and clay resulting from chemical weathering. The common intermixture of these two grades is believed to be the result of rapidly flowing streams "suddenly reaching the sea and depositing their entire load "unsorted."

In a preface to the report, S. Bracewell, director of the Geological Survey of British Guiana, emphasizes the importance of the possible occurrence of Cretaceous or older Tertiary rocks beneath the younger unconsolidated sediments of the continental shelf and, commenting on the surprisingly high velocity of the 11,000 feet-per-second conglomerate, suggests comparison with the conglomerates of the Mesozoic (?) Kaieteurian series. In reading the description of the sediments in the lower part of the Rose Hall well, the reviewer was struck with considerable lithologic and mineralogic resemblances to the basal Temblador formation (Cretaceous) of the southern part of the Orinoco Basin in Eastern Venezuela. Without venturing to assume any possible age equivalence, the reviewer believes the basal Temblador formation may be considered genetically comparable with the basal part of the Berbice formation in its relation to the basement rocks of the Guayana shield.

PARICUTIN VOLCANO, MEXICO, BY GRATON, WILLIAMS, AND DORF

REVIEW BY JOHN L. FERGUSON[1]
Tulsa, Oklahoma

"The Genetic Significance of Paricutin," by L. C. Graton.
"Geologic Setting of Paricutin Volcano," by Howel Williams.
"Observations on the Preservation of Plants in the Paricutin Area," by Erling Dorf. *Trans. American Geophysical Union*, Vol. 26, No. 2 (October, 1945), pp. 249–61.

These three preliminary papers, covering diverse aspects of a single geological phenomenon, the birth of a new volcano, contain much of interest to several categories of geologists.

Graton's paper assesses Paricutin as a normal and typical small volcano, which, if

[1] Review received, November 19, 1945.

studied critically during its life cycle will give direct evidence of the processes which produced thousands of similar volcanoes around the world. He suggests that a test be made in this Michoacan volcanic province of Daly's hypothesis that a genetic difference exists between principal and subordinate volcanoes. Then he initiates the discussion with preliminary evidence that the large, aligned principal volcanoes are not necessarily developed from a deeper magmatic source than the small, scattered subordinate vocanoes.

Howel Williams presents the results of a careful geological reconnaissance of an area covering 600 square miles around Paricutin. He discusses the age, type, and origin of the various volcanic rocks, noting the change from andesitic material of Tertiary age to the olivine basalt of the Pleistocene and Recent. The Michoacan volcanic province is located on the east-west volcanic belt which crosses Mexico and includes such giant cones as Orizuba, Popocatapetl, Nevada de Toluca, and Colina, as well as the areas of numerous scattered small craters located on broad lava plateaus, such as the area surrounding Paricutin. Williams points out that neither this east-west alignment nor any other of appreciable extent is evident in the pattern of the small volcanoes. The Recent volcanism has been accompanied by no large fractures, but rather by a series of small tear faults produced by horizontal movements of minor extent.

Dorf's paper is a study of "plant fossils in the making" in ash deposits, and is intended to record the proportion of the living forest which the fossils represent. This study should assist paleobotanists to restore more accurately the botanical conditions existing when older eruptions produced the fossilization of then existing forests. Dorf presents definite observations regarding the types of material which are preserved and under what conditions they are best preserved.

These papers are an indication of the breadth of the studies which can still be made around this young and active volcano. However, it is regrettable that a comprehensive program of geological, physical, chemical, meteorological, and biological studies could not have been instituted immediately after the inception of the volcano in order to preserve the priceless factual data available at this unique geological event of recent time.

RECENT PUBLICATIONS

ARKANSAS

*"Pressure Maintenance by Water Injection, Midway Field, Arkansas," by William L. Horner. *Oil and Gas Jour.*, Vol. 44, No. 28 (Tulsa, November 17, 1945), pp. 185-90; 5 figs., 2 tables.

*"*Ibid.*, *Oil Weekly*, Vol. 119, No. 12 (Houston, November 19, 1945), pp. 28-31; 5 figs., 2 tables.

CALIFORNIA

*"Gas Storage and Recent Developments in the Playa del Rey Oil Field," by F. C. Hodges. *California Oil Fields*, Vol. 30, No. 2 (San Francisco, July-December, 1944) (Published in November, 1945), pp. 3-10; 3 pls.

*"Knoxville Series in the California Mesozoic," by F. M. Anderson. *Bull. Geol. Soc. America*, Vol. 56, No. 10 (New York, October, 1945), pp. 909-1014; 15 pls.

CHINA

*"Chinese Reserves Still a Mystery," *Petrol. Engineer*, Vol. 17, No. 2 (Dallas, Texas, November, 1945), p. 184; sketch map showing provinces with proved reserves.

COLORADO

"Structure Contour Maps of the Rangely Anticline, Rio Blanco and Moffat Counties, Colorado," by C. R. Thomas, J. W. Huddle, F. T. McCann, N. D. Raman, and C. O.

Johnson. *U. S. Geol. Survey Prelim. Map 41*, Oil and Gas Inves. Ser. (November, 1945). Single sheet, 36×52 inches. For sale by Director, U. S. Geological Survey, Washington 25, D. C.; Room 314 Boston Building, Denver, Colorado; Room 234 Federal Building, Tulsa, Oklahoma. Price, $0.40.

*"Structure of the White River Plateau near Glenwood Springs, Colorado," by W. C. MacQuown. *Bull. Geol. Soc. America*, Vol. 56, No. 10 (New York, October, 1945), pp. 877–92; 3 pls., 5 figs.

*"Rangely, One-Time Shallow Field, Now Rocky Mountains' Most Active Area," by C. R. Thomas. *Oil and Gas Jour.*, Vol. 44, No. 28 (Tulsa, November 24, 1945), pp. 90–96; map, table, columnar section.

"Mesozoic and Paleozoic Stratigraphy in Northwestern Colorado and Northeastern Utah," by C. R. Thomas, F. T. McCann, and N. D. Raman. *U. S. Geol. Survey Prelim. Chart 16*, Oil and Gas Investig. Ser. (December, 1945). 2 sheets: 44×64 and 44×56 inches. Stratigraphic sections; scale, 1 inch equals 200 feet. Index map and text: May be purchased from Director, Geological Survey, Washington 25, D. C.; Federal Building, Casper, Wyoming; 314 Boston Building, Denver, Colorado; 234 Federal Building, Tulsa, Oklahoma. Price, $0.75 per set.

EGYPT

*"Egyptian Exploration Is Being Conducted on Broadest Front in History," by C. O. Willson. *Oil and Gas Jour.*, Vol. 44, No. 30 (Tulsa, December 1, 1945), pp. 56–58; 1 map.

*"Only Production in Egypt Comes from Two Fields on Suez Gulf Shores," by C. O. Willson. *Ibid.*, No. 31 (December 8), pp. 62–65; 2 photpographs, sketch map, chart of crude products.

GENERAL

**Laboratory Exercises in Physical Geology*, revised edition (1945), by William C. Putnam and Robert W. Webb. 89 pp., 4 pls., 7 figs. 8.5×11 inches, paper covers, spiral binding. Published by Stanford University Press, California. Price, $1.00.

*"Behavior of Water-Input Wells," by Parke A. Dickey and Kurt H. Andresen. *Oil and Gas Jour.*, Vol. 44, No. 28 (Tulsa, November 17, 1945), pp. 205–16; 249–74; 23 figs.

**Ibid.*, "Pt. 1," *Oil Weekly*, Vol. 119, No. 12 (Houston, November 19, 1945), pp. 38–40, 44; 4 figs.

*"Pennsylvanian Rocks and Fusulinids of East Utah and Northwest Colorado Correlated with Kansas Section," by M. L. Thompson. *Kansas Geol. Survey Bull. 60*, Pt. 2 (Lawrence, October 1945). 84 pp., 6 pls., 11 figs.

Oil and Gas Field Development to United States 1944, Vol. XV (1945), by National Oil Scouts and Landmen's Association. Annual review of geological and geophysical prospecting, land and leasing activities, wildcat exploration, proved field development, oil and gas production, pipe line and refinery statistics. Edited under direction of Howard R. Brooks, editor-in-chief; E. J. Raisch, assistant editor. 926 pp. Austin, Texas. Price, $7.50.

*"Electric Log Interpretation: Part 1, Location of Sand-Type Reservoirs," by Hubert Guyod. *Oil Weekly*, Vol. 120, No. 1 (Houston, December 3, 1945), pp. 33–42; 12 figs.

*"Precision in Bottom-Hole Pressure Measurement," by E. R. Brownscombe and D. R. Conlon. *Petrol. Tech.*, Vol. 8, No. 6 (New York, November, 1945). 14 pp., 12 figs. *A.I.M.E. Tech. Pub. 1942.*

*"A New Technique for Determining the Porosity of Drill Cuttings," by M. A. Westbrook and J. F. Redmond. *Ibid.*, 4 pp., 2 figs. *A.I.M.E. Tech. Pub. 1943.*

*"Effect of Arsenates on the Viscosity of Drilling Muds," by B. C. Craft and C. M. Moncrief. *Ibid.* 3 pp., 2 tables. *A.I.M.E. Tech. Pub. 1944.*

*"The Electrolytic Model and Its Application to the Study of Recovery Problems," by Holbrook G. Botset. *Ibid.* 10 pp., 5 figs. *A.I.M.E. Tech. Pub. 1945.*

*"The Engineering of Oil-Well Abandonments," by William E. Schoeneck. *Ibid.* 12 pp., 12 figs. *A.I.M.E. Tech. Pub. 1946.*

ILLINOIS

(1) "Subsurface Relations of the Maquoketa and 'Trenton' Formations in Illinois," by E. P. DuBois; (2) "Petroleum Possibilities of Maquoketa and 'Trenton' in Illinois," by Carl A. Bays, *Illinois Geol. Survey Div. Rept. Inv. 105* (Urbana, November, 1945). 38 pp., 2 pls., 10 figs.

Oil and Gas Map of Illinois (1945). Size, 30×51 inches. 4 colors: gray base, blue drainage, with oil and gas fields in red, and pipelines, refineries and large natural-gasoline plants in green. Order from Illinois State Geological Survey, Urbana. Price, $0.35.

LOUISIANA

Map of Louisiana (1945). Shows oil and gas fields. Sheet, 38×41.5 inches. Scale, 1 inch equals 500,000 feet. Obtainable from Louisiana Geological Survey, Geology Building, Louisiana State University, University Station, Baton Rouge, Louisiana. Price, $1.10.

MICHIGAN

*"Injection of Water into Underground Reservoirs in Michigan," by W. E. Schoeneck. *Oil and Gas Jour.*, Vol. 44, No. 28 (Tulsa, November 17, 1945), pp. 193–94; 198, 200, 202; 2 figs., 3 tables.

MONTANA

"Columnar Sections of Mesozoic and Paleozoic Rocks in the Mountains of South Central Montana," by L. S. Gardner, T. A. Hendricks, H. D. Hadley, and C. P. Rogers, Jr. *U. S. Geol. Survey Prelim. Chart 18*, Oil and Gas Investig. Ser. (December, 1945). Sheet, 44×56 inches. 3 lines of sections; scale, 1 inch equals 120 feet. May be purchased from Director, Geological Survey, Washington 25, D. C.; 303 North 27th Street, Billings, Montana; 234 Federal Building, Tulsa, Oklahoma; 314 Boston Building, Denver, Colorado; Federal Building, Casper, Wyoming. Price, $0.40.

NETHERLANDS

"The Paleocene and Eocene Stratigraphy of the Netherlands (Excepting South Limburg), according to the Foraminifera," by A. Ten Dam. *Mededeelingen van Geologische Stichting*, Ser. C, V, No. 3, Published by Ernst Van Aelst, Uitgever, Maastricht, Netherlands (1944). 142 pp., 6 charts, 6 pls. 9×11.875 inches. Paper cover. Foreword and résumé in Dutch. Text in German. This is one of a series of publications in geological-paleontological research in the subsurface of the Netherlands, under the direction of W. A. J. M. van Waterschoot van der Gracht, and W. J. Jongmans, P. Tesch, L. U. de Sitter, and collaborators.

PENNSYLVANIA

"Oil and Gas Field Farm Line Maps of the Franklin and Oil City Quadrangles, Pennsylvania," by Parke A. Dickey and L. S. Matteson. *Pennsylvania Topog. and Geol. Survey Spec. Bull. 2* (1945). 18 maps on scale of 1 inch equals 2,000 feet. May be obtained from Division of Documents, Department of Property and Supplies, 10th and Markets Sts., Harrisburg, Pennsylvania. Price, $1.25.

TENNESSEE

*"Oil and Gas in the Northern Cumberland Plateau, Tennessee," by Kendall E. Born and William N. Lockwood. *Tennessee Div. Geol. Oil and Gas Inves. 2* (1945). Single sheet,

42×34.5 inches. Map, text, 14 figs., 3 tables. Geologic sections, structural contours, well data, key maps, *et cetera*. Tennessee Division of Geology, G-5 State Office Building, Nashville 3, Tennessee.

TEXAS

*"Permian Pease River Group of Texas," by Robert Roth. *Bull. Geol. Soc. America*, Vol. 56, No. 10 (New York, October, 1945), pp. 893–908; 8 pls., 3 figs.

WYOMING

"Stratigraphic Sections and Thickness Maps of Triassic Rocks in Central Wyoming," by J. D. Love, Chester O. Johnson, Helen L. Nace, H. H. R. Sharkey, Raymond M. Thompson, Harry A. Tourtelot, and A. D. Zapp. *U. S. Geol. Survey Prelim. Chart 17*, Oil and Gas Inves. Ser. (November, 1945). Sheet, 44×64 inches. Three series of stratigraphic sections on vertical scale of 1 inch equals 100 feet. Four maps on scale of 1 inch equals 50 miles. Brief text. May be purchased from Director, Geological Survey, Washington 25, D. C. Price, $0.40.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Paleontology* (Tulsa, Oklahoma), Vol. 19, No. 6 (November, 1945)

"The Foraminiferal Fauna of the Anahuac Formation," by Joseph A. Cushman and Alva C. Ellisor

"Some New Genera of Paleozoic Gastropods," by J. Brookes Knight

"*Rectuvigerina*, a New Genus of Foraminifera from a Restudy of *Siphogenerina*," by Richard D. Mathews

"Early Ordovician Graptolites from Big Canyon, Oklahoma," by Charles E. Decker

"Devonian Conodonts from Northwestern Montana," by Chalmer L. Cooper

"Genera and Subgenera of the Pelecypod Family Glycymeridae," by David Nicol

"Restudy of Some Miocene Species of *Glycymeris* from Central America and Colombia," by David Nicol

"Amplexoid Corals from the Chester of Illinois and Arkansas," by Wm. H. Easton

"Several Upper Cambrian Fossils from the Upper Mississippi Valley and a Giant Graptolite from the Lower Middle Ordovician of Newfoundland," by W. H. Twenhofel

"Revision of Fossil Pteropoda from Southern Anatolia, Syria and Palestine," by M. Avnimelech

"Bibliography and Index to New Genera, Species, and Varieties of Foraminifera for the Year 1943," by Hans E. Thalmann

MILITARY GEOLOGY

**The Military Geology Unit: U. S. Geological Survey and Corps of Engineers, U. S. Army*. Illustrated pamphlet of 22 pages and 11 figures published by the Geological Society of America, December, 1945. "This pamphlet was prepared by members of the staff of the Military Geology Unit for distribution at the Pittsburgh (1945) meeting of the Geological Society of America. It is an informal statement; a definitive history of the Unit will be published at a future date."—*From the Prefactory Note*. A supply is available for distribution from A.A.P.G. Headquarters, Box 979, Tulsa 1, Oklahoma. Free.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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PACIFIC SECTION ABSTRACTS

The following are abstracts of papers given at the 22d annual meeting of the Pacific Section of the Association, held at the Ambassador Hotel, Los Angeles, California, November 8 and 9, 1945.

Frank S. Parker, Signal Oil and Gas Company, Los Angeles. Results of California Exploration during the War Period.

The paper continues the work Roy Barnes published in the A.A.P.G. *Bulletin* of October, 1940, on through the war period with emphasis on discoveries of the first 9 months of 1945. The trends of geophysical activity, geological employment in exploration, and the number of A.A.P.G. members in California are shown and compared with the price curve. A pronounced increase in A.A.P.G. membership is found with only a slight increase in employment in the seventeen companies considered. It is thought the employment trend is not representative as many of the smaller companies not considered have added to their staffs. The seismograph activity has fluctuated seasonally but has averaged a level trend.

Wildcat drilling as shown by the dry-hole curve has increased and broken previous records both in 1943 and 1944. The lesser increase in number of currently active wildcats

is ascribed to increased efficiency in shortening rigging-up and shut-down periods due to greater demand for rigs and crews.

A clear correlation is shown between the number of wildcats drilled and the number of discoveries made. The less obvious correlation between geological employment and discoveries may be due to the lapse of time between the working-out of a play and the drilling of it, in some cases 5 or 10 years. The increased demand and price of dry gas is reflected in the increasing number of gas field discoveries.

The correlation of reserves, production, and new reserves by discovery is discussed. The new reserves discovered have failed to keep pace with the production. The production, which reached a new high of 311 million barrels in 1944 and possibly will reach 315 million in 1945, has been maintained by increased development drilling and the discovery of new pools and extensions. By the end of the war the California reserves had declined only 185 million barrels, from 3533 million in 39 to 3348 million in January, 1945. The effect of Order M68 on development drilling is well marked by a slump, while practically no effect is visible on wildcat drilling. As was intended, that order provided materials to keep up the pace of exploration at the expense of development drilling. The prompt recovery of development activity by the fall of 1942 and its rapid increase from then through the war is illustrated by the curve.

The amount of oil found by wildcatting alone, that is, the amount of oil in the discovery pool only of the fields is compared with the total ultimate by years. The curve shows that approximately three-eighths of the oil has been in pools discovered by later exploratory drilling.

Also, it is seen that the discoveries in California have come in steps of half billion or more size additions to reserves at intervals of 8 to 10 years which are timed by advances in geologic exploration, drilling technique, and seismic exploration. The present year should be the period for another advance in discoveries according to the chart, but so far has not differed from the last 6 or 7 years in volume of oil found. The writer estimates roughly 25 million barrels of oil as the reserves of the new fields. With the data so far in hand no estimate of the new gas fields or of the new pools and extensions can be given.

The various exploration methods or combinations of them leading to the drilling of the dry holes and discoveries are compared graphically. The chart showed 20 wildcats to be successful out of a total of 202 drilled. Of these only sixteen will eventually be regarded as having found fields rather than extensions, and five of these were of dubious commercial value. The greatest footage and number of wells were drilled on subsurface work, with both seismic and surface work less and about equal. Other methods and combinations had much less footage. The over-all wildcat success percentage was 10.2%. New-pool tests were 31% successful and outposts 42% successful. It appears that at the present rate 1945 will end with somewhat less wildcat footage but with a greater number of wells drilled. Other types of exploratory wells will exceed substantially 1944 both in footage and number.

EVAN BURTNER, Standard Oil Company of California, Taft. Buena Vista Hills (27-B Pool).

The Buena Vista oil field is situated on the southwestern edge of the Great Valley of California immediately north and east of the town of Taft. It has produced oil since 1909 from two formations, the San Joaquin clays and Etchegoin, both of Pliocene age. Although the "27-B" pool was not discovered until March, 1944, the sand had been penetrated as early as 1915, but because of unfavorable structural position, no production was realized.

The hills consist of two major anticlines, the United and the Honolulu, in northwest-southeast *échelon*, each anticline having separate closure, but with production continuous across the saddle. Limiting closure is determined at the intersection of the United anticline on its northwest plunge, with the Midway Valley syncline. Closure in the Pliocene in-

creases with depth, due to over-all thinning in a southeasterly direction, to a point of minimum section at about the NW. ¼ of Sec. 9, 32-24. The southwest flanks of the folds are locally oversteepened, without resultant shift of axes, suggestive of similar folding. A probable fault, referred to as the "Maguire" fault, separates the old "Maguire" sand pool from the "27-B" pool. The "Maguire" sand is considered to be the southeastern extension of the "27-B" sand.

The assignation of the "27-B" sand to the Etchegoin (Pliocene) is considered erroneous. Conclusive faunal evidence is lacking, but from other evidence available at present, a Pliocene-Miocene break is preferred above the "27-B" sands.

A maximum net sand thickness of about 110 feet occurs in Sec. 36, 31-23. The individual sand lenses (E_1-E_4) pinch out not far downdip on the northeast flank of the hills, at higher structural elevations than is the case on the southwest flank. This is the apparent reason for the much higher water table on the northeast flanks,—a case of water entrapment against a permeability barrier. Edge water on the southwest flank is found to be 300 feet structurally lower than the structural spill point. This is explained by pinch-out of the individual sand lenses in the W. ½ of Sec. 28, 31-23.

At the peak of the war demand the pool produced at average rates as high as 40,275 barrels per day. The current maximum efficient rate is set at 25,000 barrels per day, which permits top wells a daily production of 180 barrels, subject to a gas restriction in the case where a well produces gas at rates in excess of 600 cubic feet per barrel.

The absence of a water drive will probably require some form of pressure maintenance for maximum oil recovery.

Joseph Hollister, consultant, Gaviota, California. Geology of Tierra del Fuego, South America.

The paper is a brief résumé of the stratigraphy and structure of that part of Chile. The presence of a Cretaceous-Tertiary basin, 20,000 feet or more deep, east of the main Cordillera, is pointed out and the suggestion made that a landmass lay on the west as well as one on the east of this basin during late Mesozoic and Tertiary time.

Thomas Clements, University of Southern California, Los Angeles. Stratigraphic Section East of Bogotá, Colombia.

A geologic traverse was made by the author in 1939 along the road from Bogotá to Villavicencio, a distance of 122 kilometers. The purpose was to attempt to correlate the rocks of the little known east side of the Cordillera Oriental with the better known formations of the Magdalena Valley on the west side of the mountains.

The rocks exposed along the traverse are sedimentary and metamorphic, and range in age from possible Cambrian to Pleistocene; only the Cretaceous rocks yielded abundant fossils. Igneous rocks reported to occur both north and south of the line of traverse were not encountered in this particular section, although the basal conglomerate of the Cretaceous contains fragments of granite.

The formations observed along the road, with their respective ages, are the following: Quetame, Cambrian (?); Vinculo, Devonian (?); Pipiral, Carboniferous (?); Colorado, Permian (?); La Argentina, Cretaceous (?); Cáqueza, Cretaceous (Lower Valanginian); Villeta, Cretaceous (Upper Valanginian, Hauterivian, Barremian, and Aptian); Guadalupe, Cretaceous (Middle Albian and Cenomanian); Buena Vista, Tertiary (?); Guaduas, Tertiary, Eocene (?); terraces, Pleistocene.

The principal structural features are the Bogotá fault, an overthrust to the west; the Cáqueza fault, an overthrust to the east; the San Martín fault, normal, with the westerly block downthrown; the Argentina fault, normal, with the easterly block downthrown; and the Cientoquince fault, an overthrust to the east. In addition, the Guada-

lupe formation is folded into a large, gentle syncline, and all the rocks show a very great number of small folds.

R. A. STIRTON, University of California, Berkeley. The First Oligocene Mammalian Fauna from Northern South America.

Fossil vertebrate remains were found on the northwest limb of the San José anticline south of the Rio Tetuán and approximately 10 kilometers northeast of Chaparral, Tolima, in the upper Magdalena region, Colombia. They were discovered in a thin lense of bone breccia within a blue-gray clay member (La Cira zone) of the Gualanday (Brazalosa) series.

The type La Cira from the middle Magdalena was called upper Oligocene by A. A. Olsson as based on a fresh-water invertebrate fauna. The mammal remains from Chaparral indicate a relationship close to the Deseado lower Oligocene of Argentina.

Tentative faunal list: Chelonian, crocodilian, ground-sloth, toxodont (? *Proadinotherium*), litoptern (? *Prothesodon*), astrapothere (near *Uruguaytherium*), and ? condylarth.

JOHN C. REED, United States Geological Survey, Washington, D. C. Recent Investigations by the Geological Survey of Alaska Petroleum Possibilities.

Because of the acute national situation in regard to oil during the war, the Geological Survey initiated detailed examinations in the summer season of 1944 in a number of the areas that, on the basis of considerable reconnaissance work over nearly half a century were considered most likely to contain petroleum. In 1944 these studies were undertaken in five widely separated localities and similar investigations were continued in 1945. From them and the earlier more general examinations, three large areas are indicated as of most immediate significance. These may be designated as the Gulf of Alaska area, the Alaska Peninsula-Cook Inlet area, and northern Alaska. In each of these regions are a number of structures or other indications regarded as favorable for the possible accumulation of petroleum and that therefore seem worthy of intensive investigation.

In the Gulf of Alaska area the oil possibilities are confined to rocks of Tertiary age. Farther west in the Alaska Peninsula-Cook Inlet region, Jurassic rocks overlie a Triassic limestone that is presumed to be a possible oil source. In northern Alaska, the Navy Department is exploring the oil possibilities of Naval Petroleum Reserve No. 4 that lies in an extensive tract underlain for the most part by gently folded Cretaceous rocks. The Geological Survey is playing a part in the exploration program of the Navy Department.

Much additional information must be gathered before it is possible to estimate in quantitative terms the potential petroleum resources of Alaska. The determination of the value of these latent resources presents a challenge and the prospective returns well warrant tackling the job of determining the pertinent facts.

HORACE D. THOMAS, University of Wyoming, Laramie.
MAX L. KRUEGER, Union Oil Company of California. Late Paleozoic and Early Mesozoic Strata of the Uinta Mountains, Utah.

At the western end of the Uinta Mountains, Triassic rocks rest unconformably on the Permian Park City formation. From the base upward the Triassic rocks are (1) red Woodside shale, (2) marine Thaynes limestone, (3) Ankareh redbeds, and (4) a conglomerate and overlying sandstones and shales. The conglomerate, sandstones and shales were classed as basal Nugget sandstone, Jurassic, by Boutwell (1912), but were excluded from the Nugget (Navajo) by Heaton (1939), leaving them without a name. The Thaynes thins and tongues out eastward, and east of its edge the Woodside and the Ankareh can not be differentiated.

At the eastern end of the mountains, Woodside redbeds rest on the Pennsylvanian

Weber sandstone. The lower part of the Woodside is the time equivalent of the upper Park City (Phosphoria). The Woodside is cut by an unconformity, above which lies a conglomerate. The conglomerate was questionably classed as the basal member of the Ankareh by Sears (1926). The upper part of the Ankareh (?) of Sears consists of varicolored shales and sandstones and is directly overlain by the massive Navajo sandstone.

The conglomerate and the overlying varicolored beds are readily recognized from one end of the range to the other and constitute an unnamed lithologic unit which lies unconformably above the type Ankareh and below the restricted Nugget at the western end of the mountains, and unconformably above the Woodside and below the Navajo at the eastern end of the range. This unit is here named the Stanaker formation and the basal conglomerate, or grit, is named the Gartra grit member of the Stanaker formation. They are probably Upper Triassic in age.

The Jurassic formations of the western Uinta Mountains, from base upward are (1) Nugget sandstone, (2) Twin Creek limestone, (3) Preuss redbeds, (4) Stump sandstone, and (5) Morrison formation. Eastward along the mountains (1) the Nugget sandstone persists but is called Navajo to the east, (2) the Twin Creek limestone intertongues with the Carmel redbeds, (3) the Preuss redbeds grade into the cross-bedded Entrada sandstone, (4) the Stump sandstone grades into Curtis shales and limestones, and (5) the Morrison thins and becomes less conglomeratic. At the eastern end of the Uinta Mountains the Carmel redbeds thin out so that the Navajo is directly overlain by the Entrada, forming a single cross-bedded sandstone unit.

N. L. Taliaferro, University of California, Berkeley.
W. F. Barbat, Standard Oil Company of California, Taft. Notes on the Geology of the Deep Coles Levee Well, Kern County, California.

The Standard Oil Company of California's well K.C.L. 20-13 attained a depth of 16,246 feet in 1944. The section penetrated includes 3560 feet of combined Tulare and San Joaquin formations, 3110 feet of Etchegoin formation, 1630 feet of the Reef Ridge shale, 1000 feet of McLure shale above the Stevens sand, 880 feet of Stevens sand, and 1875 feet of McLure shale below Stevens and above *Pulvinulinella gyroidinaformis*. The interval from *P. gyroidinaformis* at 12,056 feet to the top of the Santos shale at 15,230 feet consists mostly of cemented sandstone and firm, nearly barren, silty shale. Middle Miocene foraminifers were found at 13,423 feet and the Olcese and Rio Bravo-Vedder sand zones are recognized in the intervals 13,906–14,073 and 14,900–15,230 feet respectively. The Santos shale is very hard and dense below 15,800 feet where the electric-log character changes. A decrease of about 25 millivolts from the normal shale line and an increase in resistivity of 2 to 3 times that of the overlying shale are noted. Shale porosities drop from 3.4% and 2.3% at 15,539 feet and 15,651 feet to 1.03% and 0.29% at 15,981 feet and 16,166 feet. Petrographic studies by Taliaferro are incomplete and can not be reported in time for this presentation.

Core dips are low (3°–10°) to 13,000 feet, then gradually rise to 65° at 16,166 feet. The maximum temperature at 16,186 feet was 400°F.

Subject to possible modification by the petrographic study, it is tentatively concluded that no metamorphic minerals have been formed by the load and shearing stresses of folding involved, but the rock at bottom is approaching the limit to which fine-grained sediments can be compressed without such changes.

Edward C. H. Lammers, Standard Oil Company of California, Los Angeles. Notes on Rocky Mountain Thrust Faults.

The low-angle thrust faults of the central Rocky Mountains are of two types. The faults along the Idaho-Wyoming border were formed when the exceptionally thick Paleozoic and Mesozoic strata of the Cordilleran geosyncline were intensely compressed during

the Laramide revolution. Movement on these faults, which do not involve the crystalline rocks of the basement complex, is believed to have been dissipated at depth by shearing along bedding planes. The name "geosynclinal" thrust fault is proposed for faults of this type.

In contrast, the low-angle thrust faults of central Wyoming and southern Montana were produced by the further compression of large faulted blocks previously uplifted during an earlier stage of the Laramide revolution. The crystalline cores of these uplifts contributed large quantities of detritus to the Paleocene strata forming the foot-wall blocks of some of the thrusts. A study of the structures of the basement complex indicates that the present uplifts occupy the sites of pre-Cambrian mountain ranges. Hence, this group of thrust faults borders areas that have been recurrently structurally positive throughout geologic time. The name "geanticlinal" thrust fault is proposed for thrust faults of this type.

BAILEY WILLIS, Stanford University. Terrestrial Dynamics.

The progress in physics and geology requires a revision of geologic theories. We now know that the earth has a molten core, 4,000 miles in diameter, which is covered by a shell 1,800 miles thick, that is solid and mostly crystalline. It is called the mantle. And there is an outer crust 20 to 30 miles thick. The effective forces operating throughout this structure are gravity or load pressure, heat, and atomic attractions and repulsions. The heat may be attributed to compression and radioactive disintegration of atoms, but probably not to survival from an originally molten globe. In this hypothesis it is regarded as mainly due to radioactive processes.

It is reasonable to assume that radioactive minerals are present in the core and are its principle source of heat. Since the heat cannot escape the core must be heating and growing at the expense of the mantle. The earth is growing hotter, not cooling.

The boiling core emits gases and superheated liquids that bore into the mantle and form bubbles of magma. The bubbles rise by virtue of their bouyancy and boring activity. Their mineral composition changes by assimilation and adjustment of mineral species to environment. Starting from the core as nickel-iron and accessories they emerge in the crust as basalt and granite.

The mechanics of the pressure in and around a bubble of magma give it the shape of a pear, biggest at the top. On approaching the surface this effect develops the tack-shaped batholith. The cover over such a batholith is liable to uplift, indicated at the surface by elevated plateaus and broad domes or elongate swells, and to metamorphism, which may produce lateral pressures. The unbalanced load of an elevated mass also creates lateral pressure. Under certain circumstances the effect of lateral stress and strain in combination with magmatic heat may produce extensive horizontal intrusions 20 miles below the surface. Such a one is thought to have been the mass under the Appalachian geosyncline during the Paleozoic era. To that mobile foundation we may attribute the sinking of the sediments, and by a logical development of load stresses in combination with magmatic pressures we may explain the folding of the Appalachians, the outthrust of the Himalayas, and similar displacements.

Bubbles of igneous rock have risen to the surface at intervals during the last 2 billion years. They consist of two principle kinds, basalt and granite. They differ in fluidity or viscosity. The basalt reaches the surface and spreads out, forming such features as ocean beds and plateaus. The granite lifts the surface without breaking through, causes lateral stresses, and becomes the core of a mountain range. The possible mechanical effects are varied. We can not reason from one orogeny to another, without due consideration of the facts of unlike histories. The Appalachian mechanics will not explain the Rockies, or the Basin ranges, or the Alps. Each orogeny is a problem in itself. But they all are to be ex-

plained through a study of the reactions of the forces of gravity, magmatic intrusion, and atomic activity.

The prolonged sequence of intrusions of the surface by magmatic bubbles is regarded as the source of the crust. The process is not finished or ever can be, since radioactive disintegration continues to heat the core. We may infer that the thinning mantle will ultimately disappear and the planet will become a star.

Claude Leach and Henry H. Neel, Tide Water Associated Oil Company, Ventura. Landslides-Ventura Avenue Oil Field.

The soft Pliocene formations in the Ventura district are particularly susceptible to landsliding. Resultant movement has presented difficult and expensive problems in connection with the development of oil-producing properties. Extensive work has been undertaken by the Tide Water Associated Oil Company in an effort to stop existing slides and to prevent the development of new slides in the Ventura Avenue oil field.

The landslides in this field are of two types, bedding-plane slides and circular-type slides. Bedding-plane slides move along parallel bedding planes in areas where the dip of the formation exceeds 15° and is in the same direction as the surface slope. Circular-type slides are independent of the stratification of the formation. They occur in stratified material which is not dipping in the same direction as the surface slope, and in unstratified material such as old slides where the bedding has been destroyed.

The two principal causes of landsliding are the presence of water in the formation and the disturbance of equilibrium. Water is probably the most important cause for it lowers the coefficient of friction within the slide itself and along existing slide planes, reduces the shear and tensile strength of the formation, increases the weight of the landslide mass, and creates a lifting force due to hydrostatic pressure in the lower part of the slide. The state of equilibrium may be disturbed by a redistribution of weight by either natural or artificial means.

Three basic methods of landslide control are practiced in the Ventura Avenue field. They are the removal of water from the slide, the elimination of the source of the water, and the redistribution of the load. Water is removed by nearly horizontal "Hydrauger" holes, vertical water-well shafts, drain tiles, and tunnels. Elimination of the source of the water is accomplished by dressing and oiling the surface to facilitate rain-water run-off, and by preventing waste water, drilling mud, et cetera, from seeping into the formation. Redistribution of the load consists in removing earth from the head of the slide and compacting this material at the toe.

It is perhaps too early to judge the full effect of the corrective measures employed. However, results of observation in the past 3 years indicate that the measures taken have been highly successful.

FINAL REPORT OF COMMITTEE ON METHOD OF ELECTION OF OFFICERS[1]

The committee on method of election of officers, a special committee appointed in 1944 to consider possible methods of electing Association officers by the use of a mailed ballot, and reappointed in 1945 to study the results of a questionnaire on the same subject, has completed its study of methods of election, reviewed the results of the questionnaire, and reports the following conclusions.

1. A majority of Association members, answering the questionnaire, wish to change to

[1] John G. Bartram, chairman; Ronald K. DeFord, W. Dow Hamm, John Smith Ivy, Hugh D. Miser, Clarence L. Moody, and Earl B. Noble. Submitted to M. G. Cheney, chairman of the executive committee, October 27, 1945.

a mailed-ballot method of election that will allow all members to vote in the annual elections.

2. The committee recommends that the Association change its method of election to a mailed-ballot method, as follows.
   a. The executive committee shall appoint a nominating committee of five members, two of whom shall be past-officers of the association.
   b. The nominating committee shall nominate one or more members for each of the Association's elective offices, and shall publish its nominations in the September *Bulletin.*
   c. After the nominations are published in the September *Bulletin,* additional nominations can be made by written petitions signed by fifty or more members and received at Association headquarters on or before November 15.
   d. The executive committee shall then print a ballot and mail it immediately to all members. The executive committee shall have charge of the election and decide all questions of eligibility or procedure.
   e. The time for the return of ballots shall extend from the date of mailing in November through January 31 of the ensuing year.
   f. The ballots shall be returned to Association headquarters and there placed unopened in a locked ballot box.
   g. Immediately after January 31 a ballot committee, appointed by the president, shall open the ballot box, count the ballots, and report the election results.
   h. A majority of all votes cast for an office shall be necessary for election. If more than two members are nominated for any office, a preferential type ballot, as described later, shall be used, to obviate the necessity of a second or run-off election.
   i. The term of the newly elected officers shall begin at the close of the next ensuing annual meeting. The election will be announced in February and their term will begin in March or April of the same year.

The committee on method of election of officers submits, at the end of this report, a suggested set of amendments to the constitution and by-laws, which, if adopted, would provide the method of election here recommended.

History of Committee

In 1944, the business committee received a petition proposing that the method of electing officers be changed to a particular method of mailed ballot. Since other methods had previously been discussed, action was taken to appoint a seven-man special committee to study the problem for one year and to determine the best possible method of election by mailed ballot. That investigation was completed, the report submitted, and later was published in the May, 1945, *Bulletin.* It was anticipated that the business committee would, at the 1945 annual meeting, consider the report and make appropriate recommendations to the annual business meeting of the Association.

However, due to wartime conditions, the annual business meeting was poorly attended and not sufficiently representative to decide such important recommendations of the business committee. Action was taken to postpone its consideration for one year; to conduct during the year a questionnaire straw ballot on many questions concerning methods of election; and to appoint a seven-man method of election committee to study the results of the questionnaire and to recommend a system of election. This committee's report was to be submitted November 15, 1945, to be published in the January, 1946, *Bulletin,* and to be considered at the 1946 annual meeting of the business committee.

All seven members of the previous committees were reappointed. A questionnaire, which is included below, was prepared by chairman Bartram, approved by the executive

committee, and mailed to all Association members on May 1, 1945, to be returned to Association headquarters before July 1, 1945. The returned questionnaires were counted and tabulated by staff employees at Association headquarters. The final vote on all questions is shown on the copy of the questionnaire printed below.

QUESTIONNAIRE
(May 1, 1945)
METHOD OF ELECTING OFFICERS

The method of electing the Association's officers is being considered by the executive and business committees in response to requests from some members that the method be changed to a mailed ballot that would permit all members to vote, and not limit the election to those at the annual meeting. Last year a special committee made a study of method of election by mail ballot. Its report is published in the May *Bulletin*. It is not a recommendation for or against a mail ballot. Before acting on any proposed changes, it has been decided to canvass the opinions of the members by means of a questionnaire which will also serve as a "straw ballot." The following recommendation of the executive committee was adopted by the business committee at the annual meeting, March 27. It is published in the May *Bulletin*.

"That the attached questionnaire or one designed to accomplish the same purpose be sent to the membership before May 1, 1945; that a committee of 7 be appointed by the president to study all replies received by July 1, 1945; that the committee recommend a system of election based upon the replies; that the committee send its report to the executive committee by November 15, 1945; that the report be published in the January, 1946, *Bulletin;* and that the report be considered at the annual meeting of the business committee in 1946."

Please read this questionnaire carefully, vote your preference on each question, and return to Association Headquarters promptly.

[Note: The numerals after each ☐ indicate the total vote cast]

1. *Present Method vs. Mailed Ballot*

Do you prefer to retain the present method whereby nomination, election, and induction of new officers all occur during the Annual Meeting, or do you prefer to change to some method of mailed ballot?

Retain present method ☐ 317 Change to mailed ballot ☐ 1026

2. *Election Before or After Annual Meeting*

If it is decided to change to a mailed ballot method, the actual balloting or election must occur either before or after the Annual Meeting. Do you prefer that the election be held before the meeting, which will require nominations beforehand, but will permit induction of new officers at the Annual Meeting, or do you prefer that the election be after the meeting, which will permit nomination at the meeting but require induction of new officers at a later date?

Prefer election before meeting ☐ 871 Prefer election after meeting ☐ 353

3. *Method of Nomination*

A. If the nomination and election occur before the meeting, how shall the nominations be made? Indicate your preference.
(1). By a nominating committee ☐ 218
(2). By petitions signed by members ☐ 95
(3). By a nominating committee, plus other nominations by petitions ☐ 590
(4). By district representatives ☐ 218
(5). By any other method or methods (Explain) ☐ 26

B. If the election occurs after the meeting and the nomination can be at the meeting, how shall the nominations be made? Indicate your preference.
(1). From the floor (as at present) ☐ 359
(2). From the floor plus later petitions signed by members ☐ 492
(3). Another method or methods (Explain) ☐ 43

C. If a nominating committee is used, how shall it be formed?
(1). Appointed by the President ☐ 98
(2). Appointed by Executive Committee ☐ 328
(3). Appointed by Business Committee ☐ 182
(4). Elected by members at Annual Meeting ☐ 267
(5). An automatic committee, such as five most recent past presidents, etc. ☐ 191
(6). Another method (Explain) ☐ 60

D. Of whom shall the nominating committee be composed?
  (1). Any members ☐ 594
  (2). District representatives ☐ 396
  (3). Past officers ☐ 169

E. How many individuals shall the nominating committee nominate for each office (that is, how many slates of nominees)?
  (1). One nominee for each office ☐ 94
  (2). Two nominees for each office ☐ 598
  (3). One or more nominees for each office ☐ 444

F. If nominations are to be by petition, how many members should be required on a petition?
  (1). 25 members ☐ 408
  (2). 50 members ☐ 479
  (3). — members (Fill in your preference) ☐ 154

4. *Induction of officers*
   If the election is held after the Annual Meeting, when shall the new officers be inducted?
   A. Soon as election certified ☐ 528
   B. At next Annual Meeting ☐ 304
   C. At some other specified date ☐ 77

5. *Remarks or other Methods*

Signature____________________
(Optional and not required)

Date________________, 1945

Location of member________________, ________________
City State

(IN ORDER TO BE COUNTED, THIS MUST BE RETURNED TO A.A.P.G. HEADQUARTERS, BOX 979, TULSA 1, OKLAHOMA, BEFORE JULY 1, 1945)

Results of Questionnaire

Questionnaires were mailed to 3263 members and 1243, or 40 per cent, were returned. It was hoped that a larger percentage would indicate their preferences on these questions, but a check on the experience of other mailed ballots in this and similar organizations indicates that 40 per cent is a fair return. Many people refuse or neglect to return such mailed questionnaires. The committee therefore believes that the vote accurately represents the preferences of the Association members. In this connection, it is interesting that only 50 to 64 per cent of the members registered at the regular annual meetings, made the effort to vote, even when active campaigns were conducted for competitive candidates.

Year	*Members Registered*	*Members Vote*	*Percentage Voted*
1936	636	315	50
1939	710	455	64
1941	1043	548	52

The membership of the Association is divided geographically into 25 districts, and the returned questionnaires were sorted into these districts for counting. The results (Table I) show that in 23 districts a majority voted for a change to a mailed ballot, and in only two districts was the vote to retain the present system. Members in New Mexico voted 100 per cent to change and in Michigan 93 per cent, and 21 districts ranged between 89 and 60 per cent to change. Only Dallas with 49 per cent and Amarillo with 37 per cent were against changing.

The questionnaire vote on the different questions shows that the members preferred—
Question 2. Election before meeting.
Question 3-A-3. Nominations by a nominating committee, plus other nominations by petitions.

TABLE I

RESULTS OF QUESTIONNAIRE ON METHOD OF ELECTING OFFICERS
(May 1–July 1, 1945)

Association District	*Number Ballots Sent Out*	*Number Ballots Returned*	*Percentage Returned*	*Voted to Retain Present System*	*Voted to Change to Mailed Ballot*	*Percentage for Change to Mailed Ballot*
Amarillo	20	8	40	5	3	37
Appalachian	125	47	37	10	37	78
Canada	46	31	67	8	23	74
Capital	98	38	38	9	29	76
Corpus Christi	54	10	18	3	7	70
Dallas	123	51	41	26	25	49
East Oklahoma	299	116	39	26	90	77
Fort Worth	85	43	50	17	26	60
Great Lakes	149	61	41	13	48	78
Houston	378	177	47	38	139	79
Michigan	37	15	40	1	14	93
New Mexico	34	16	47	0	16	100
New York	137	53	39	7	46	87
Pacific Coast	413	148	36	53	95	64
Rocky Mountains	134	63	47	11	52	83
Shreveport	99	38	38	5	33	87
South America	142	39	27	9	30	77
Southeast Gulf	103	45	43	5	40	89
S. Louisiana	82	28	34	4	24	85
S. Permian Basin	172	82	47	11	71	87
South Texas	141	64	45	25	39	61
Tyler	46	21	46	3	18	86
West Oklahoma	170	58	34	13	45	77
Wichita	135	59	44	7	52	88
Wichita Falls	41	24	59	6	18	75
Other Foreign		8		2	6	75
Total	3263	1343	40	317	1026	76

Question 3-C-2. Nominating committee appointed by executive committee.
Question 3-D-1. Nominating committee composed of any members.
Question 3-E-2. Nominating committee to nominate two or more nominees for each office.
Question 3-F-2. 50 members required on each petition.

The method of election, now recommended by this committee, follows, generally, the questionnaire vote, but differs on two points—

1. Instead of permitting any member to serve on the five-man nominating committee (Question 3-D-1) it is recommended that at least two of the five nominating committee members be past-officers of the Association. The reason is that the Association's business is both important and complex and the advice of some experienced past-officers is needed when selecting future officers.

2. The method of election committee considers it unwise to require two or more nominees to be nominated for each office (Question 3-E-2) and recommends that the nominating committee "nominate one or more for each office." The reason is that it will frequently be impossible to get anyone to run against an especially strong candidate, and elections between strong and weak candidates will have little value. Seldom could two

nominees for the editorship be available. The provision, "one or more nominees," will permit any nominating committee to nominate two for any or all offices, if they desire to do so.

Many Association members wrote remarks or discussions of other methods in the space provided on the questionnaire for that purpose. These were sorted and read by chairman Bartram, who reported on them to other members of the committee, for proper consideration.

Preferential Form of Ballot

The present constitution does not require a majority for election to an Association office, but since the proposed method of election can produce several nominees for any office, it is now recommended that a majority of the votes cast for any office be necessary for election. If there are three or more nominees for an office, the first count may not give any nominee a majority. Since a second or run-off election (as was proposed in last year's report of this committee) would be slow and expensive, it is now reconmended that a preferential form of ballot be used, as outlined below, so that the election may be settled in a fair manner with one mailed ballot.

If there are three or more nominees for any office, the ballot shall provide boxes or squares in which the voter can show numerically, 1, 2, 3, *etc.*, his order of preference for the nominees. On the first count, the ballot committee shall count only the first-choice votes. If no candidate receives a majority, the candidate with the fewest first-choice votes shall be eliminated and the second choice on his ballots shall be counted as first choice for the remaining candidates. This procedure shall continue until one candidate has a majority. This method is used satisfactorily in many municipal elections.

Amendments to Constitution and By-Laws

The method of election committee has prepared the following amendments to the constitution and by-laws, which, if adopted, will provide the recommended method of election by mailed ballot. The constitutional amendments should be acted upon at the 1946 annual meeting, and if approved, could be ratified by mailed vote of the members following the 1946 meeting. The amendments to the by-laws should be considered at the 1947 annual meeting, if the constitution is amended during 1946, or they might be provisionally approved at the 1946 meeting, subject to approval and ratification of the constitutional amendments.

Proposed Amendments
Constitution
ARTICLE IV. OFFICERS AND THEIR DUTIES

SECTION 2. The officers shall be elected annually from the Association at large by MEANS OF SECRET MAILED BALLOT IN THE FOLLOWING MANNER: THE NOMINATING COMMITTEE SHALL NOMINATE ONE OR MORE CANDIDATES FOR EACH OFFICE, AND ITS NOMINATIONS SHALL BE PUBLISHED IN THE SEPTEMBER BULLETIN. ADDITIONAL NOMINATIONS MAY BE MADE BY WRITTEN PETITION OF FIFTY, OR MORE, MEMBERS IN GOOD STANDING RECEIVED AT ASSOCIATION HEADQUARTERS NOT LATER THAN NOVEMBER 15. THE EXECUTIVE COMMITTEE SHALL THEN PREPARE A PRINTED BALLOT, LISTING THE CANDIDATES FOR EACH OFFICE, AND ONE BALLOT SHALL BE MAILED TO EACH MEMBER AS SOON AFTER NOVEMBER 15 AS POSSIBLE. BALLOTS RETURNED TO ASSOCIATION HEADQUARTERS ON OR BEFORE JANUARY 31 SHALL BE PLACED AS RECEIVED IN A LOCKED BALLOT BOX AND PROMPTLY AFTER JANUARY 31 THE BALLOT COMMITTEE SHALL OPEN THE BALLOT BOX AND COUNT THE BALLOTS. BALLOTS OF DELINQUENT MEMBERS SHALL NOT BE COUNTED. A MAJORITY OF ALL VOTES CAST FOR AN OFFICE IS NECESSARY FOR ELECTION. IF THERE ARE THREE OR MORE NOMINEES FOR ANY OFFICE, A PREFERENTIAL FORM OF BALLOT SHALL BE USED. IN CASE OF A TIE VOTE, THE EXECUTIVE COMMITTEE SHALL CAST ONE ADDITIONAL DECIDING VOTE. Each candidate

for the particular office for which he is nominated, shall be thereby automatically voted for as a candidate for the executive committee for one year, except that candidates for the presidency shall be automatically voted for as candidate for the executive committee for two years.

SECTION 4. The president shall be the presiding officer at all meetings of the Association, shall take cognizance of the acts of the Association and of its officers, shall appoint such committees as are required for the purposes of the Association, EXCEPT THE NOMINATING COMMITTEE, and shall delegate members to represent the Association. He may, at his option, serve on and be chairman of any committee, EXCEPT THE NOMINATING COMMITTEE.

SECTION 8. The officers shall assume the duties of their respective offices immediately after the annual meeting, WHICH FOLLOWS THEIR ELECTION.

ARTICLE V. EXECUTIVE COMMITTEE—MEETINGS AND DUTIES

SECTION 3. The executive committee shall consider all nominations for membership and pass on the qualifications of the applicants; shall have control and management of the affairs and funds of the Association; shall determine the manner of publication and pass on the material presented for publication; shall designate the place of the annual meeting; SHALL APPOINT THE NOMINATING COMMITTEE AND ITS CHAIRMAN; AND SHALL BE IN CHARGE OF THE ANNUAL ELECTION OF OFFICERS AND DECIDE ELIGIBILITY AND OTHER QUESTIONS PERTAINING TO THE ELECTION. They are empowered to establish a business headquarters for the Association, and to employ such persons as are needed to conduct the business of the Association. They are empowered to accept, create, and maintain special funds for publication, research, and other purposes. They are empowered to make investments of both general and special funds of the Association. Trust funds may be created, giving to the trustees appointed for such purpose, such direction as to investments as seem desirable to the executive committee to accomplish any of its objects and purposes, but no such trust funds shall be created unless they are revocable upon ninety (90) days' notice.

ARTICLE VI. MEETINGS

The Association shall hold at least one stated meeting each year, which shall be the annual meeting. This meeting shall be held in March or in April at a time and place designated by the executive committee. At this meeting the election of members shall be announced, the proceedings of the preceding meeting shall be read, Association business shall be transacted, scientific papers shall be read and discussed and officers for the ensuing year shall be ANNOUNCED.

BY-LAWS

ARTICLE VI. COMMITTEES

SECTION 1. There shall be the following standing committees: business committee; research committee; committee on geologic names and correlations; committee on applications of geology; committee for publication; finance committee; committee on statistics of exploratory drilling; trustees of revolving publication fund; trustees of research fund; and medal award committee.

The president shall appoint all standing committees except the business committee and the medal award committee, for which provision is hereafter made. Members of all committees except the business committee shall serve for a three-year term, but in rotation, with one-third of the members being appointed each year. The president shall designate the chairmen, annually, shall have power to fill vacancies, and shall notify the members of the committees of their appointment. The president may designate one or more vice-chairmen annually.

In addition to the aforesaid standing committees, THE EXECUTIVE COMMITTEE SHALL

APPOINT ANNUALLY A NOMINATING COMMITTEE AND ITS CHAIRMAN, the president shall appoint ANNUALLY A BALLOT COMMITTEE, and annually or semiannually a resolutions committee, and such special committees as the executive committee may authorize. Special committees shall be appointed for a term of one year. The president shall designate the chairmen of such committees.

Nominating Committee

SECTION 13. THE PURPOSE OF THE NOMINATING COMMITTEE IS TO NOMINATE CANDIDATES FOR ASSOCIATION OFFICES AS PROVIDED IN THE CONSTITUTION. THE COMMITTEE SHALL CONSIST OF A CHAIRMAN AND FOUR OTHER MEMBERS APPOINTED BY THE EXECUTIVE COMMITTEE TO SERVE ONE YEAR. AT LEAST TWO MEMBERS OF THE NOMINATING COMMITTEE SHALL BE PAST OFFICERS OF THE ASSOCIATION.

Ballot Committee

SECTION 14. THE FUNCTION FO THE BALLOT COMMITTEE IS TO COUNT THE BALLOTS RECEIVED IN THE REGULAR ANNUAL ELECTION AND TO REPORT THE FINAL RESULTS TO THE PRESIDENT. A PREFERENTIAL FORM OF BALLOT SHALL BE COUNTED IN THE FOLLOWING MANNER: THE BALLOT COMMITTEE SHALL COUNT FIRST CHOICE VOTES ONLY. IF NO CANDIDATE RECEIVES A MAJORITY, THE CANDIDATE WITH THE FEWEST VOTES SHALL BE ELIMINATED AND THE SECOND CHOICE ON HIS BALLOTS SHALL BE COUNTED AS FIRST CHOICE FOR THE REMAINING CANDIDATES. THE COMMITTEE SHALL CONTINUE THIS PROCEDURE UNTIL ONE CANDIDATE HAS A MAJORITY.

DEFERMENT OF SCIENTIFIC AND TECHNICAL PERSONNEL

OFFICE OF SCIENTIFIC PERSONNEL BULLETIN 26

The long awaited shift in Selective Service policy has been announced in releases to the press dated November 30. Administration interest in reversing previous policy had been strongly indicated as long ago as the last week in August, but final action was subject to a number of delays. The new memoranda are reproduced herewith from advance copies mailed to State headquarters.

It will be noted from Local Board Memorandum 115-M, Part I, 2, that an advisory committee has been set up to advise the Office of War Mobilization and Reconversion on, among other things—Part I, 2, (4)—"release of men from the armed services." Basic changes of policy in this connection are expected to be announced shortly.[1]

Local Board Memorandum 115 has been liberalized. Those familiar with the earlier Local Board Memorandum 115 will note that Part II, 1, General Rule, indicates a change to omit the requirement that a registrant be "indispensable." The requirement that no person shall be deferred when a veteran is available to fill the post has likewise been dropped.

The Selective Service System appears to feel that between the provisions of the new memoranda the deferment of scientific and technical personnel has been generally provided for. Cases now active where the registrant appears to lack satisfactory classification should be immediately reopened for new classification in the light of the new releases. Local boards generally should be willing to re-examine each case. It would be advisable for the employer to request reconsideration in the light of the changed policy.

M. H. TRYTTEN, *Director*
Office of Scientific Personnel

NATIONAL RESEARCH COUNCIL
WASHINGTON, D. C.
November 30, 1945

[1] Editorial note.—On December 20 the newspapers carried the announcement of a further reduction of points for discharge for both officers and enlisted personnel and also the announcement that thereafter no more fathers would be inducted.

SELECTIVE SERVICE LOCAL BOARD MEMORANDUM 115
(AS AMENDED 11/26/45)
SUBJECT: OCCUPATIONAL CLASSIFICATION OTHER THAN AGRICULTURE AND MERCHANT MARINE

PART I—GENERAL POLICIES

1. *General.*—(a) This memorandum describes the policies and procedures which govern occupational classification of registrants ages 18 through 25. The classification of registrants engaged in agriculture is governed by sections 622.25-1 and 622.25-2 of the Regulations and the classification policies and procedures for registrants engaged in the Merchant Marine of the United States and the merchant marine of a cobelligerent nation are stated in Local Board Memorandum No. 115-H.

(b) The policies stated in this memorandum shall not be construed to interfere with the classification into Class I-A, Class I-A-O, or Class IV-E of (1) a registrant age 18 through 25 who is a delinquent, or (2) a registrant age 18 through 25 who leaves the employment for which he was deferred without a determination by his local board favorable to his leaving, or (3) a registrant who volunteers for induction and is placed in a class available for service under section 624.4 of the Regulations.

2. *Objectives in classification.*—It is the objective of the Selective Service System to select and forward for induction the number and type of men required by the armed forces and to accomplish this result without disrupting activities in support of the national health, safety, or interest.

3. *Term used in occupational classification.*—The term "national health, safety or interest" as used in the Selective Training and Service Act, the Regulations and Local Board Memoranda may be construed to include (1) the production and services required to maintain the armed forces of the United States during the period of the occupation of enemy territory; (2) research, development and manufacturing of weapons or other items necessary to the maintenance of adequate national defense; (3) transportation and other activities required for the demobilization of our armed forces; (4) activities and services required for an expeditious reconversion from a wartime to a peacetime economy; and (5) other activities which the local board considers essential on a national or local basis.

PART II—CLASSIFICATION POLICIES AND PROCEDURES

1. *General rule.*—A registrant age 18 through 25 may be retained or placed in Class II-A:

(a) If the local board finds that he is "necessary to and regularly engaged in" an activity in support of the national health, safety, or interest; or

(b) If he is found to be disqualified for any military service or found to be qualified for limited military service only, and the local board finds that he is "regularly engaged in" an activity in support of the national health, safety, or interest.

2. *Applicable forms.*—(a) Form 42A (Special-Revised) will continue to be used for the making of requests for the occupational deferment of registrants ages 18 through 25, except those found to be disqualified for any military service or found to be qualified for limited military service only.

(b) Form 42 should be used for the making of requests for the occupational deferment of registrants ages 18 through 25 who are found to be disqualified for any military service or found to be qualified for limited military service only, and will bear on the face thereof the words "Disqualified for any military service" or "Qualified for limited military service only." Such registrants will be identified by letter suffix in accordance with section 622.83 of the Regulations.

. . . .

4. *Consideration for registrants in national defense of reconversion.*—Local Boards will

give most serious consideration to the deferment of registrants for whom there is on file or is hereafter filed a Form 42A (Special-Revised) if they come within one of the groups described as follows:

(a) *Registrants in the national defense projects.*—Registrants for whom a Form 42A (Special-Revised) is filed and in whose case the local board determines that they have technical or scientific qualifications and who are engaged in research, development or production of weapons or other items required in maintaining adequate national defense.

(b) *Key personnel in reconversion activities.*—Registrants for whom a Form 42A (Special-Revised) is filed and in whose case the local board determines that they have supervisory, technical or scientific qualifications and hold such a position that their removal would retard reconversion and would result in the reduction of hiring of veterans and others by the employer.

5. *Consideration in other special situations.*—It will continue to be necessary for the Director of Selective Service to issue Local Board Memoranda covering situations which require special consideration for classification in Class II-A. Situations will vary in the period of time required for special consideration, the region or area involved and the type of personnel included, and will be described in other Local Board Memoranda in the 115 series or by special instructions from the Director of Selective Service through the State Directors. Therefore, registrants ages 18 through 25 for whom Forms 42A (Special-Revised) are filed and whom the local board determines are covered in one of the Local Board Memoranda or special instructions of the Director will be given special consideration for classification in Class II-A.

6. *Consideration of fathers.*—In considering the classification or reclassification into Class II-A of a registrant age 18 through 25, if all other factors are equal, preference will be given a father. For the purposes of classification in Class II-A, the local board will determine whether a registrant is a father or a nonfather by applying the provisions of section 622.32 (b) and (c) of the Regulations.

7. *Registrants who are reexamined after rejection.*—Under the provisions of Local Board Memorandum No. 77-E certain registrants ages 18 through 25 who are in Class II-A (F) and Class II-A (L) may be forwarded for preinduction physical examination to determine if they may now be qualified for general military service or acceptable for military service under the provisions of Local Board Memorandum No. 77-F. Employers may not have on file with the local board a Form 42A (Special-Revised) for such registrants. Therefore, if such a registrant is found to be qualified for general military service or acceptable for military service under the provisions of Local Board Memorandum No. 77-F upon preinduction physical examination and is placed in Class I-A, Class I-A-O, or Class IV-E as a result thereof, the local board may attach to Form 59 a statement notifying the registrant's employer that he has the opportunity to file Form 42A (Special Revised) within 10 days of the mailing of the Notice of Classification. When a Form 42A (Special-Revised) is filed for such a registrant, and if it finds the registrant to be eligible for Class II-A under the provisions of Part II of this memorandum, it shall reopen his case and consider his classification anew.

8. *Local board report.*—In order to provide the Director of Selective Service with accurate information concerning the classification of registrants ages 18 through 25 under the provisions of this memorandum, the local board will report as follows:

(a) When a Form 42A (Special-Revised) has been filed, the local board immediately after taking action with respect to the registrant will make sure that the registrant's order number on the front of the Form 42A (Special-Revised) is correct, and complete the Report of Local Board on the back of the duplicate copy of such form and will transmit the duplicate copy to the Director of Selective Service, Gimbel Building, Philadelphia, Pennsylvania, attached to the Local Board Action Report (Form 110) for the local board meeting at which such action was taken.

PART III—MISCELLANEOUS INFORMATION AND GUIDES

1. *Federal Government employees.*—Federal Government employees age 18 through 25, will be considered for occupational deferment under Part II of the memorandum on the same basis as registrants in private employment, provided that the provisions of Executive Order 9309 and Local Board Memorandum No. 115-F are complied with. Every Form 42A (Special-Revised) or Form 42 which is filed for such registrants must be identified as an "Authorized Government Request."

2. *Employer's responsibility.*—Employers are under a continuing responsibility to notify local boards of the termination of employment of a registrant age 18 through 25 for whom they have requested deferment and also of any change of the basis on which the deferment was requested.

3. *Registrant engaged in seasonal occupation.*—A registrant engaged in a seasonal occupation who is qualified for occupational deferment shall be continued therein, even though he moves from one locality to another for the purpose of following local seasons, provided that during the off-season he engages in an activity in support of the national health, safety, or interest, and provided further, that upon the reopening of the season he returns to his seasonal occupation.

LEWIS B. HERSHEY
Director

SELECTIVE SERVICE LOCAL BOARD MEMORANDUM 115-M
(ISSUED: 11/26/45)

SUBJECT: SPECIAL CONSIDERATION FOR CERTAIN STUDENTS, TEACHERS, AND RESEARCH WORKERS IN THE PHYSICAL SCIENCES

PART I—STATEMENT OF GENERAL POLICIES AND PROCEDURES

1. *General.*—The demands of the armed forces and industry during the emergency have resulted in a curtailment in advanced studies for men having high technical and scientific qualifications. Since the cessation of active fighting, the demands of long range national interest require a resumption of these studies in order to fully develop the technical and scientific skills which have been acquired and to provide adequate teaching facilities for returhing veterans who desire to resume their studies in these fields.

2. *Reconversion working committee on deferment and selective release.*—(a) Pursuant to a request from the Director of War Mobilization and Reconversion, the Reconversion Working Committee on Deferment and Selective Release has been established to assist in the accomplishment of this purpose. The Committee is composed of representatives of the (1) Office of Scientific Research and Development; (2) Civilian Production Administration; (3) Office of Rubber Reserve; (4) Petroleum Administration for War; (5) War Department; (6) Navy Department; (7) United States Employment Service; (8) Office of Education; (9) National Roster of Scientific and Specialized Personnel; and the (10) Selective Service System. The Chairman of the Committee will be the Director of War Mobilization and Reconversion, or a staff member designated by him. The functions of the Committee are to:

(1) Indicate to the Director of War Mobilization and Reconversion the specific occupations in which shortages of personnel threaten to interfere with the national health, safety, or interest.

(2) Formulate the specific standards indicating that a man is qualified to engage in a selected occupation.

(3) Certify to the Director of the Selective Service System those individuals meeting the standards established by the Committee.

(4) Indicate to the War and Navy Departments the categories of occupations in which shortages detrimental to the national interest could be relieved by release of men from the armed forces.

PART II—CERTIFICATION PLAN

1. *Operation of plan.*—The Director of the Office of War Mobilization and Reconversion will examine all proposals by the Committee relating to deferment and release, and shall transmit to the Selective Service System and the War and Navy Departments all approved proposals. The Director will transmit the recommendations for deferment to local boards through the appropriate State Directors.

2. *Classification policies.*—Pursuant to the provisions of this memorandum and under the general authority contained in paragraph 5 of Part II of Local Board Memorandum No. 115, as amended, local boards will give serious consideration to the occupational deferment of registrants engaged in the technical and scientific fields set forth in Part III of this memorandum.

PART III—STANDARDS AND PROCEDURES

1. *Advanced studies in the physical sciences or engineering.*—(a) Any registrant who is accepted by an accredited college or university as a candidate for a Master's or Doctor's degree in the physical sciences or engineering may be certified by the Office of War Mobilization and Reconversion to the Director of Selective Service as essential to the national interest in a civilian capacity.

(b) The fact that a candidate for a Master's or a Doctor's degree may engage in part-time employment or other activities will not affect his certification under this paragraph so long as his academic standing is satisfactory.

2. *University teaching in the physical sciences or engineering.*—Any registrant who is to be employed by an accredited college or university as a teacher of physical sciences or engineering may be certified by the Office of War Mobilization and Reconversion to the Director of Selective Service as essential to the national interest in a civilian capacity.

3. *University research in the physical sciences or engineering.*—(a) Any registrant (1) who is to be employed by or attached to the staff of an accredited college or university for research in the physical sciences or engineering and (2) who signifies his intention to engage in such an activity may be certified to the Director of Selective Service as essential to the national interest in a civilian capacity.

(b) Such a registrant will be certified only if (1) the research to the undertaken by the registrant contributes significantly to the national interest, and (2) inability of the individual registrant to undertake the research will result in its delay.

4. *Submission of information in certain cases.*—Any registrant who wishes to be certified under the provisions of paragraphs 1, 2, and 3 above, must present to the Office of War Mobilization and Reconversion, Washington, D. C., the following documents in triplicate:

(a) A notarized statement of his intention:

(1) To undertake graduate studies leading to a Master's or Doctor's degree in the physical sciences or engineering; or

(2) To engage in the teaching of physical sciences or engineering; or

(3) To undertake advanced research in the physical sciences or engineering on the staff of or attached to a college or university.

(b) A statement from an accredited college or university signed by a responsible official of the college or university, indicating that the registrant:

(1) Has been accepted as a candidate for a Master's or Doctor's degree in the physical sciences or engineering; or

(2) Has been accepted as a teacher of physical sciences or engineering; or

(3) Is to be employed by or attached to the staff of the college or university for research in the physical sciences or engineering, together with a statement indicating in detail the nature of the research to be performed by the registrant, the scope of the registrant's responsibilities for the research, and the necessity for securing the individual registrant for the work.

(c) A statement showing the registrant's name, address, age, Selective Service local board number and address, classification, and educational qualifications.

5. *Study leading to a B.S. or B.A. degree in physical sciences or engineering.*—(a) Any registrant who has satisfactorily completed at least three years of work leading to a Bachelor's degree in the physical sciences or engineering may be certified by the Office of War Mobilization and Reconversion to the Director of Selective Service as essential to the national interest in a civilian capacity, provided such registrant has served for a period of not less than two years in a project directly connected with the war effort.

(b) Any registrant who wishes to be certified under the provisions of this paragraph must present to the Office of War Mobilization and Reconversion, Washington, D. C., the following documents in triplicate:

(1) A notarized statement of his intention to continue undergraduate studies leading to a B.S. or B.A. degree in the physical sciences or engineering.

(2) A statement from an accredited college or university, signed by a responsible official of the college or university, indicating that the registrant has been accepted for the fourth year of study in a course leading to a B.S. or B.A. degree in the physical sciences or engineering.

(3) A statement showing the registrant's name, address, age, Selective Service local board number and address, classification, and educational qualifications.

(4) A statement from the registrant's employer that he has been engaged for at least two years in scientific war work.

LEWIS B. HERSHEY
Director

The executive committee desires to remind the members and associates that the Association offers the facilities of the Headquarters office to those seeking employment. The committee desires in particular to offer its services to those who have served in the Armed Forces and are now released and seeking employment. File a complete record of your education and experience with J. P. D. Hull, business manager, Box 979, Tulsa, Oklahoma. He will bring your qualifications to the attention of those who have filed their needs with his office. A member of the national service committee will be available for counsel.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

Rocks and Rivers of America, by ELLIS W. SHULER, was recently published by the Jaques Cattell Press of Lancaster, Pennsylvania. It is a well illustrated book of 300 pages, written from the cultural and popular point of view. The author is Hamilton professor of geology and dean of the Graduate School of Southern Methodist University at Dallas, Texas.

THOMAS S. HARRISON, consulting petroleum geologist of Denver, Colorado, spoke on "Oil and Gas Record within the Rocky Mountain Region," at the annual meeting of the Rocky Mountain Oil and Gas Association at Casper, Wyoming, December 7-8.

The following geologists are executives of the Standard Oil Company of Texas: GAGE V. LUND, chairman of the board of directors; T. J. GALBRAITH, vice-president in charge of exploration; and E. S. WHITE, vice-president and manager of production.

FRED M. BULLARD, of the geology faculty of the University of Texas, Austin, gave his illustrated lecture on "The Mexican Volcano, Paricutin," before the South Texas Section of the A.A.P.G. at San Antonio, Texas, December 5.

W. J. GILLINGHAM, of the Schlumberger Corporation, gave an illustrated talk on "The Interpretations of Electrical Logs in North Louisiana and Mississppi," before the New Orleans Geological Society, December 3.

HOMER C. MOORE, formerly chief geologist of the Mid-Continent Petroleum Corporation, is now president of Oil Exploration, Inc., McBirney Building, Tulsa, Oklahoma.

K. H. CRANDALL, who has been vice-president and director of the California Company, New Orleans, Louisiana, since the company began active drilling operations in Mississippi and Louisiana, is now president and J. W. HOOVER is vice-president in charge of exploration.

JESS H. HENGST, recently in the employ of the Barnsdall Oil Company is district geologist for the Ryan Oil Company at Evansville, Indiana.

RALPH W. IMLAY, of the United States Geological Survey, gave an illustrated lecture on "Jurassic and Lower Cretaceous History of the Gulf Region," before the New York Academy of Sciences, Section of Geology and Mineralogy, at the American Museum of Natural History, New York City, December 3.

W. PHILIP COX, recently with the Petroleum Administration for War, Foreign Division, is now in the producing department of the Socony-Vacuum Oil Company, Inc., 26 Broadway, New York City.

M. KING HUBBERT, who is associate director of research for exploration, Shell Oil Company, Inc., gave an illustrated address on "Geologic Inventions," at a meeting of the Houston Geological Society, November 26.

W. G. GREEN, president of Engineering Laboratories, Inc., is president of Tulsa Industries, Inc., recently organized as a cooperative venture in promoting reconversion for Tulsa manufacturers.

WILLIAM D. LEWIS was released from the Navy on October 24 and is on the geological

staff of the General Petroleum Corporation of California, Los Angeles. He served as a photo-interpreter for 3 years: in the Mediterranean theater 2 years, and in the Pacific 6 months, with amphibious forces.

G. C. PFEFFER has left the Tide Water Associated Oil Company at Los Nietos, California. He is in the employ of the Venezuelan Atlantic Refining Company, Maturin, Estado Monogas, Venezuela.

E. F. MARTI has been discharged from the Navy and has returned to work for the Independent Exploration Company as party chief of a crew working for the Texas Petroleum Company, in Colombia, S. A.

CYRIL K. MORESI has returned from the Navy and is in consulting geological work. His address is Box 126, Jeanerette, Louisiana.

ROBERT B. MCCONNELL has gone to Caracas, Venezuela, for the Venezuelan Atlantic Refining Company.

H. C. COOKE has been discharged from the Navy as Lieutenant (jg). For the past year he was commanding officer of the U.S.S. *ATA-124*, an ocean tug for the Pacific Service Force. Prior to that he was in the C B's for 2 years in the South Pacific. He is in the employ of the Southern Minerals Corporation, Corpus Christi, Texas.

The Rocky Mountain Association of Petroleum Geologists listened to ROGER RHOADES talk on "Case Histories in Engineering Geology," at Denver, Colorado, December 3.

J. V. Howell and E. R. ALBERT, JR., appeared before the Tulsa Geological Society, December 3, with "Notes on the Geology of Prince Edward Island, Canada, and a Discussion of the Drilling of Island Development Company's Hillsborough Well, the Deepest Well in the British Empire."

The Mountain Fuel Supply Company announces the appointment of WILLIAM T. NIGHTINGALE, of Rock Springs, Wyoming, as general manager of production, transmission and exploration, effective November 1, 1945. Nightingale, who has been with the company since its organization in 1929, was formerly in charge of lands and geology. He was made a vice-president in 1940 and elected to the board of directors in 1942. He has been active in geological work in the Rocky Mountain area with The Ohio Oil Company and Mountain Fuel Supply Company, since 1926.

JAMES MCNAB recently returned to the United States after 3 years overseas with the Air Forces in India, China, and the Central Pacific. During this period he served as Intelligence Officer with the 58th Bomb Wing of the Twentieth Air Force, and more recently, with the 8th Air Force on Okinawa where he held a commission as Major. McNab has returned to civilian life and may be addressed at Azusa, California, in care of WALLACE GORDON.

The Department of Geology of the University of Southern California announces the following changes in teaching staff. THOMAS CLEMENTS has been appointed Hancock professor of geology, with part of his time to be devoted to research under the Hancock Foundation for Scientific Research. He continues as head of the department. HOYT RODNEY GALE has been reappointed visiting assistant professor of geology. K. O. EMERY, recently geologist and head of the oceanographic section of the University of California Division of War Research at the Navy Radio and Sound Laboratory in San Diego, has joined the staff as assistant professor of geology. WILLIAM H. EASTON, formerly with the Illinois Geological Survey, and at present ensign in the Navy, is expected to take up his duties as assistant professor of geology at the beginning of the Spring semester.

NELSON HORATIO DARTON, honorary member of the Association, celebrated the 80th anniversary of his birth at Washington, D. C., December 17. He commenced his career with the United States Geological Survey in 1886.

NORMAN D. NEWELL, who has been with Ingenieros de Minas, Lima, Peru, for 3 years, is taking up duties at Columbia University, New York City, as professor of paleontology, and at the American Museum of Natural History, Central Park West at 79th Street, New York City, as curator of paleontology and historical geology. Newell was at the University of Wisconsin before he went to Peru.

LAURENCE BRUNDALL, formerly with Shell Oil Company, Tyler, Texas, A. R. WASEM, formerly at Louisiana State University, V. ZAY SMITH, formerly with British-American Oil Producing Company, Port Arthur, Texas, and J. C. HERMAN III, formerly of Yale University, are the board of directors of Geophoto Services, Inc., located in Denver, Colorado. They have recently been discharged from the Navy where they served as Photographic Intelligence Officers. Geophoto Services will specialize in the applications of aerial photographic analysis to petroleum geology.

HARRY M. HUNTER, of Calgary, Alberta, Canada, has been released from active duty in the Canadian Army. He commenced his recent military service in September, 1939, and was subsequently in Great Britain and on the Continent.

LAWRENCE N. DEXTER has changed his connection from the National Geophysical Company to the Atlantic Refining Company.

JOHN R. ELLIS, JR., has been released into the inactive Naval Reserves since October 6, 1945, and is working for the Carter Oil Company since November 1. His home mailing address is c/o J. R. Ellis, Helena Agency, R.F.C., Helena, Montana.

CHESTER M. GARDINER, petroleum geologist and valuation engineer, announces the removal of his offices to 110 Emporium Building, 133 East Philadelphia Street, Whittier, California.

J. J. ZORICHAK, for several years on the engineering staff of the Petroleum Administration for War, Denver, Colorado, is chairman of the engineering committee for supervising procedure in the Rangely field, Colorado.

PAUL J. HOWARD, consulting engineer and geologist has opened an office in Bakersfield, California.

The achievement award of the Florida Academy of Sciences has been presented to GARALD G. PARKER, geologist in charge of the office of the United States Geological Survey Water Division in Miami. Parker won the honor for his paper on "The Effect of the Pleistocene on the Geology and Ground Water of Southern Florida," published in the *Quarterly Journal* of the Academy, June, 1945.

Major JOHN L. LESTER, a veteran of the European Theater of Operations, has been assigned as S-3 (operations officer) of the Field Artillery School Training Detachment No. 2 at Fort Sill. From December, 1944, until his return to the United States in October, 1945, Major Lester was assistant S-4 (supply) of XXIII Corps Artillery through the campaigns in the Rhineland and Central Europe and during the occupation period since V-E Day. A graduate of the University of Illinois, Major Lester received his commission as a reserve officer in the Reserve Officer Training Corps of the University in 1937. He completed the Basic Officers' course at the Field Artillery School in June, 1943, and the Officers' advanced course in November, 1944. Prior to being called to active duty, Major

Lester was a geologist with the Shell Oil Company, Inc., Tulsa, Oklahoma. His present home address is 814 Ferris Street, Lawton, Oklahoma.

WILLARD M. PAYNE, recently with the California Company and R. MERRILL HARRIS, recently with the Union Sulphur Company, have formed a partnership under the name of Harris and Payne, geologists, 100 East Pearl Street, Jackson, Mississippi.

Structure of Typical American Oil Fields, Volumes I and II, published by the Association in 1929 has been unavailable in stock for several years. As requests have been received from a number of members for a reprinting of these books, the executive committee, in December, issued a postcard request to the membership in order to determine if the demand is large enough to permit republication at a price not to exceed $4 for Volume I and $5 for Volume II. If anyone interested has not mailed the return card, he is requested to mail it now, indicating his desire for reprinted copies. If the demand is sufficient and the plan found practicable, the work will be done by offset lithography, thus reproducing exactly the text of the originals.

ROY JAY HOLDEN, head of the department of geology, Virginia Polytechnic Institute, Blacksburg, Virginia, died, December 17, 1945, at the age of 75 years. He had been connected with the Institute since 1905 and professor of geology and mineralogy since 1908.

CHARLES W. HONESS, of the Gulf Refining Company, Evansville, Indiana, has been elected secretary-treasurer of the Indiana-Kentucky Geological Society, succeeding JESS H. HENGST, resigned.

Outgoing officers for the past year in the San Joaquin Geological Society, Bakersfield' California, are: GLEN LEDINGHAM, chairman; J. D. CERKEL, vice-chairman; and H. W. WEDDLE, secretary-treasurer. Incoming officers are: H. W. WEDDLE, chairman, Standard Oil Company of California; W. T. WOODWARD, vice-chairman, United States Geological Survey; and FLOYD L. JOHNSON, secretary-treasurer, Honolulu Oil Corporation.

After 3½ years on active duty in the U. S. Naval Reserve, LEON O. WIRINGA returned to service with Shell Oil Company, Inc., in San Antonio, Texas, on December 1, 1945.

CHARLES R. CANFIELD, district geologist for the Stanolind Oil and Gas Company at Wichita Falls, Texas, has been promoted to assistant division geologist with headquarters at Tulsa, Oklahoma.

E. B. PARMELEE, of the Texas A & M College, College Station, Texas, talked on the "Midway-Wilcox Relationships in the Bauxite District of Arkansas," at the regular luncheon meeting of the Houston Geological Society, December 10, at the Texas State Hotel, Houston.

CARLTON BEAL announces the opening of an office for the practice of petroleum engineering with respect to subsurface geology, valuation of oil and gas properties, and development and operation of oil and gas wells, 1139 Subway Terminal Building, 417 South Hill Street, Los Angeles 13, California.

JOSEPH A. SHARPE, vice-president of C. H. Frost Gravimetric Surveys, Inc., spoke to the Oklahoma City Geological Society, Oklahoma City, Oklahoma, on November 21 and to the Kansas Geological Society, Wichita, Kansas, on the occasion of its annual dinner meeting on December 18, on the subject "Necessity for Geologic Participation in the Prosecution of Geophysical Surveys."

The National Research Council announces that the closing date for applications for

the predoctoral fellowships in the natural sciences, which it is administering under a grant from the Rockefeller Foundation, will be February 1, 1946. These fellowships, as announced in September, are to assist young men and women, whose graduate training in the natural sciences was prevented or interrupted by their war activities, to complete their work for the doctorate. Candidates should send in their applications at once, and—in any case—prior to February 1, 1946, even though they may be unable to begin their graduate work until a later date. Information concerning the fellowships and nomination-application blanks have been mailed out widely to graduate schools and wartime research laboratories. They may also be obtained by writing directly to the Secretary, Committee on Predoctoral Fellowships, National Research Council, 2101 Constitution Avenue, N. W., Washington 25, D. C.

W. D. KELLER, associate professor of geology at the University of Missouri, returned to Columbia, Missouri, in December after having been at the United States Army University Center at Florence, Italy, teaching geology to American soldiers since September 1. Courses in physical and structural geology, mineralogy, and physical geography were offered to service men and women in the University Training Command. The Army geology staff was favored by being accompanied on several field trips to various points of geologic interest from the Brenner Pass on the north to Naples, Italy, on the south, by CARLO MIGLIORINI, professor of geology at the University of Florence, pre-war consultant of the A.G.I.P. Petroleum Company of Italy, and now geologist for the Allied Commission; and ADRIANO VALDUGA, Assistenti Incaricato in the University of Florence. Professor Migliorini is in accord with American geologists who believe that more petroleum will be found in Europe if a plan of extensive exploration like that followed in America is adopted on the continent.

RALPH B. CANTRELL announces that he is associated with CECIL HAGEN in consulting geology and petroleum production, with offices at 2510 Gulf Building, Houston, Texas. His connection with the Lane-Wells Company as petroleum geologist and engineer for 6½ years terminated on January 1.

SHERMAN A. WENGERD, Lieutenant Commander, U. S. N. R., went on inactive service, December 15, and is back with the Shell Oil Company, Inc., assigned as a geologist in the Wichita Falls, Texas, district. His work in geology, geodetics, hydrography, and photogrammetry for the Navy took him to Baffin Island in 1944, and to the Arctic slope of Alaska in 1945.

THOMAS L. BAILEY has resigned as consulting senior geologist for the Shell Oil Company in Los Angeles to accept a position in charge of geological exploration with the Rothchild Oil Company of Santa Fe Springs, California. His address is 223 Chrisman Avenue, Ventura, California.

CHARLES LAURENCE BAKER, recently in the employ of the Tide Water Associated Oil Company, San Francisco, California, is on the staff of the South Dakota Geological Survey, Vermillion.

President MONROE CHENEY's itinerary of visits with local groups of Association members in December and January included the geological societies at Jackson, Mississippi; Tallahassee, Florida; New Orleans and Lake Charles, Louisiana; and Houston and San Antonio, Texas.

Major JOHN MURO GOLDEN, of Boston, Massachusetts, was killed in an automobile wreck in Germany in 1945. Before entering the armed services as a reserve officer in April, 1942, he was with the Elflex Company, Houston, Texas. Major Golden was 45 years of age.

Morris H. Benson, a graduate of Texas A and M College in June, 1940, has been employed for geological work with the Mid-Continent Petroleum Corporation, Tulsa, Oklahoma.

New officers of the Rocky Mountain Association of Petroleum Geologists, Denver, Colorado, are: president, J. W. Vanderwilt, mining geologist, Midland Savings Building; first vice-president, C. A. Heiland, Heiland Research Corporation; second vice-president, Robert McMillan, Frontier Refining Company; secretary-treasurer, A. W. Cullen, Continental Oil Company, 1024 Continental Building, Denver 2.

Max David has resigned from his position as district geologist for the Phillips Petroleum Company and has a consulting office at Midland, Texas.

John Eliot Allen, chief geologist of the Oregon State Department of Geology and Mineral Industries, Portland, Oregon, has completed a paper on "The Geology of the San Juan Bautista Quadrangle, California," for publication in the *California Journal of Mines and Geology*

Richard Hughes, geologist, announces the removal of his office to 1411 Hunt Building, Tulsa, Oklahoma, for consulting, reports, appraisals, valuations.

Alex W. McCoy, III, recently with the Deep Rock Oil Corporation, is with the Phillips Petroleum Corporation, 220 Research Building, Bartlesville, Oklahoma.

Paul Weaver, of the Gulf Oil Corporation, Houston, Texas, spoke on "The Geological History of Formation of Salt Deposits" at the meeting of the Tulsa Geological Society, December 17.

Richard A. Smith, State geologist of Michigan, recently passed his 69th birthday and now looks forward to a somewhat less active professional life. He has been with the Michigan Geological Survey since 1911 and has been State geologist since 1919.

Willis P. Martens is now party chief of a field reflection-seismograph crew for the Seismograph Service Corporation, Tulsa, Oklahoma.

S. Morse Willis has opened an office for consulting practice at 917 McBirney Building, Tulsa, Oklahoma. For many years, he was in the employ of the Carter Oil Company.

Russell H. Dicken, formerly with the Republic Oil Company, is in the employ of the Plymouth Oil Company, Sinton, Texas.

Willard L. Day has left the Halliburton Oil Well Cementing Company and is working for the General Crude Oil Company at Houston, Texas.

Morris B. White is with the Princeton Refining Corporation, Shreveport, Louisiana.

John A. Liming was discharged from military service on October 26. His office address is consulting geologist, 1111 Hunt Building, Tulsa, Oklahoma.

Gerald N. Smith, formerly with the United Geophysical Company, Pasadena, California, is chief geophysicist for the Mid-Continent Petroleum Corporation, Tulsa, Oklahoma.

Paul M. Buttermore, who has been for several years with the Petroleum Administration for War in Washington, D. C., has joined the geological staff of the Danciger Oil and Refining Company, Fort Worth, Texas.

J. A. CUSHMAN, paleontologist of Sharon, Massachusetts, has been awarded the Hayden Gold Medal in Geology by the Academy of Natural Sciences of Philadelphia, "as a reward for the best publication, exploration discovery, or research in the sciences of geology and paleontology, or in such particular branches thereof as may be designated."

C. R. MCCOLLOM has closed his office as consultant and is retiring to a new home, after February 1, at 6009 Avenida Crista, La Jolla, California, where he will be available for California property consultation only.

RAYMOND CHORNEY terminated his connection with The Texas Company on December 1 and is now employed as geologist by the Pacific Western Oil Corporation in the Casper, Wyoming, office.

JAMES S. CULLISON, assistant professor of geology at the Missouri School of Mines Rolla, has been employed as senior paleontologist by the Creole Oil Corporation, Caracas, Venezuela.

GLEN M. RUBY, of United Geophysical Company, Punta Arenas, Chile, was in New York at the end of 1945, *en route* to China. It is expected he will return to South America in February.

DEVERE F. ALLEN is with the Sunland Refining Corporation, Fresno, California.

HARRY J. MCCREADY, JR., is back in geophysics work after 4 years of naval service. His address is 5441 West 48th Avenue, Wheatridge, Colorado.

JAY B. WHARTON, JR., has been released by the Navy and has returned from active duty in the South Pacific to resume his pre-war position as geologist and micropaleontologist with Bates and Cornell, consulting petroleum geologists and engineers of Lafayette, Louisiana. He was a senior grade Lieutenant, specializing in photographic interpretation.

MARK W. MITCHELL, formerly geologist for Sinclair in Mexico and more recently petroleum engineer with the Severance and Power Tax Unit of the Louisiana State Treasury Office in Baton Rouge, Louisiana, has resigned to join Bates and Cornell, consulting petroleum geologists and engineers of Lafayette as geologist.

The Penrose Medal of the Geological Society of America was presented on December 28, to FELIX ANDRIAS VENING MEINESZ, professor of geophysics in the University of Utrecht, chairman of the Netherlands Geodetic Commission, and now in this country as delegate for science of the Netherlands Government. The medalist invented a multiple pendulum which can be swung in a ship at sea and so used to measure the value of gravity beneath the oceans. The Penrose Medal is awarded only at such times as the G.S.A. Council may decide, "in recognition of prominent research in pure geology and outstanding original contributions or achievements which mark a decided advance in the science of geology."

During the year 1945 the San Joaquin Geological Society, Bakersfield, California, held ten regular dinner meetings with a speaker at each meeting. The Society records 97 geologists in the San Joaquin Valley.

Jan. 23, CHARLES E. WEAVER, A.A.P.G. distinguished lecturer, University of Washington, "Geology of Oregon and Washington and Its Relation to the Possible Occurrence of Oil and Gas."

Feb. 14, Lieutenant Colonel FRANK HORNKOHL, U. S. Army Air Forces, "Experiences with Army Air Forces and New Things in Chemistry."

Mar. 13, Lieutenant TED L. BEAR, U. S. Navy, "Role of Aerial Photography in the Invasion of Europe."

April 24, FRED M. BULLARD, A.A.P.G. distinguished lecturer, University of Texas, "Paricutin, Mexico's Newest Volcano."
June 12, ROBERT W. CLARK, Western Gulf Oil Company, "The Stratigraphy of the Mid-Continent."
July 10, GRANT W. CORBY and ROBERT M. KLEINPELL, consultants, "Geology of the Philippines and Internment Camp Experiences."
Aug. 27, ROBERT T. WHITE, Barnsdall Oil Company, "Principles of Stratigraphic Terminology."
Sept. 11, E. C. H. LAMMERS, Standard Oil Company of California, "Use of Minor Structures in the Interpretation of Large Structures."
Oct. 9, Captain JAMES W. SHELLER, U. S. Army Air Forces, "Experiences with the 8th Air Force."
Dec. 11, PAUL J. HOWARD, consultant, "Valuation of Oil and Gas Property."

H. B. STENZEL, geologist with the University of Texas Bureau of Economic Geology and secretary-treasurer of the Society of Economic Paleontologists, and HELEN JEANNE PLUMMER, consulting geologist with the Bureau of Economic Geology, at Austin, have been appointed to the Joint Committee on Zoological Nomenclature for Paleontology in America to cooperate with the International Commission on Zoological Nomenclature.

J. R. PEMBERTON, succeeds the late JOHN C. MERRIAM as a member of the board of governors of the Los Angeles County Museum of History, Science, and Arts.

GRANT W. CORBY, consulting geologist of Los Angeles, is returning to the Philippines to resume his work of exploration for petroleum with the Far East Oil Company and the Commonwealth Government's National Development Company.

Newly elected officers of the Kansas Geological Society, Wichita, Kansas, are: president, HAROLD O. SMEDLEY, Skelly Oil Company; vice-president, PAUL A. HARPER, Cities Service Oil Company; secretary-treasurer, FRANCIS E. METTNER, Transwestern Oil Company. MELVERN F. BEAR was elected a member of the board of directors for a 2-year term

The Military Geology Unit: U. S. Geological Survey and Corps of Engineers, U. S. Army has been published by the Geological Society of America. It is a pamphlet of 22 pages briefly describing and illustrating the work of the Unit at home and in the war theaters. Copies are available upon request. There is no charge. Write the Secretary, Geological Society of America, 419 West 117th Street, New York 27, N. Y., or A.A.P.G. Headquarters, Box 979, Tulsa 1, Oklahoma.

MORRIS C. MINTON, of Dallas, Texas, was engineering officer on various destroyers of the U. S. Navy from 1942 to 1945. He attained the rank of Lieutenant and served as chief engineer. He is now employed by the Standard Oil Company of Texas at San Antonio, Texas.

EDGAR W. OWEN, former president of the Association, commissioned as Captain in the Army Air Force in 1942, served in photographic interpretation throughout the war in the far Pacific region. As Lieutenant Colonel in December, 1945, he is on terminal leave until March 2, 1946. He is already back at work with the Lew Wentz Oil Division at San Antonio, Texas.

CHARLES W. FOWLER, JR., formerly geologist and petroleum engineer with the Pantepec Oil Company, is president, and PHIL J. LEHNHARD, formerly of Dowell Incorporated, is chief engineer, of the United Oilwell Service, S.A., Caracas, Venezuela. This is a new organization offering many of the services currently being performed by Dowell Incorporated of Tulsa, Oklahoma. The first service to be offered in Venezuela is the acidizing of oil wells.

HORACE G. RICHARDS, associate curator of geology and paleontology, Academy of Natural Sciences, Philadelphia, Pennsylvania, gave an illustrated lecture on "The Subsurface Stratigraphy of the Atlantic Coastal Plain," before the Section of Geology and Mineralogy of the New York Academy of Sciences at New York City last October.

BEN H. PARKER, vice-president of the Frontier Refining Company for the past 2 years and prominent in mining and petroleum industry circles in Colorado and the West, has been named president of the Colorado School of Mines to succeed M. F. COOLBAUGH, whose retirement was announced in October. The new president was a member of the faculty as associate professor of geological engineering from 1933 to 1943 except for the school year 1939–40, when he was on leave of absence to serve as assistant chief geologist for the Argentine Government Oil Fields, with headquarters in Buenos Aires.

ROBERT T. COX, geologist for the Atlantic Refining Company at Midland, Texas, has been awarded the Bronze Star for "outstanding leadership and organizational ability."

Lieutenant Colonel CHARLES M. CROSS has returned to his geological work with the Tide Water Associated Oil Company at San Francisco, California. He joined the military forces in 1941, and served in the Ordnance Corps at the time of his discharge in 1945. He was awarded the Bronze Star and the Croix de Guerre.

R. C. TUTTLE, of the Sunray Oil Company, Tulsa, Oklahoma, spoke on "A Theory of Diastrophism" before the Tulsa Geological Society, January 7.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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Lewis Grant Ayres, Vicksburg, Miss.
Brame Womack, W. E. Wallace, M. W. Sherwin
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Alvin E. Cheyney, Harold O. Smedley, John W. Inkster
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Harold S. Kemp, Hershal C. Ferguson, C. H. Stewart
Ralph Leonard Lupher, Elma, Wash.
Sheldon L. Glover, Ian Campbell, John H. Maxson
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Elizabeth Anne Herald, Houston, Tex.
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Elmer Paul Kneedler, Wichita, Kan.
Charles F. Bassett, Glenn G. Bartle, Edith Ann Pierce
Robert M. Leibrock, De Witt, Ark.
F. B. Plummer, Harry H. Power, Gordon Buskirk
Aniceto Horacio Torrea, Plaza Huincul, Argentina, S. A.
H. R. Wofford, Jr., Bela Hubbard, Winthrop P. Haynes

Lois Regina Wescott, Tulsa, Okla.
R. A. Brant, W. H. Butt, Castle J. C. Harvey

FOR TRANSFER TO ACTIVE MEMBERSHIP

Carlos Louis Chase, Midland, Tex.
B. L. Pilcher, Jr., Joseph H. Markley, Jr., Kenneth R. Parsons
Keith Morgan Hussey, Houston, Tex.
Henry V. Howe, H. N. Fisk, Chalmer J. Roy
Walter Neustadt, Jr., Ardmore, Okla.
Charles E. Decker, V. E. Monnett, C. G. Lalicker
George Russell Schoonmaker, Tampa, Fla.
Coe S. Mills, E. H. Rainwater, H. G. Walter

JOINT ANNUAL MEETING, STEVENS HOTEL, CHICAGO, APRIL 1–4, 1946

The Stevens Hotel is the convention headquarters for the annual meeting of the Association, April 2–4, 1946. Also, the Society of Exploration Geophysicists meets on April 1–2, and the Society of Economic Paleontologists and Mineralogists meets on April 3–4.

Hotel room reservations should be made early. Available space is limited. Make your own reservations with the Stevens Hotel. After the Stevens is full, the Stevens will refer your request to other hotels who have agreed to cooperate. You will receive your letter of confirmation from the hotel accepting the reservation. If you prefer some particular hotel, try to make your reservation directly with that hotel. The Stevens will not accept reservations for blocks of rooms.

The executive committee is arranging the convention. It is the general committee and the program committee. The sessions are tentatively arranged according to the following plan.

April 1 (Monday).	S.E.G. sessions.
	A.A.P.G. committees and research conferences.
	Annual business committee.
April 2 (Tuesday).	Joint sessions A.A.P.G., S.E.P.M., S.E.G.
	Presidential addresses.
	Papers on Application of Geology to Military Science.
	Nomination of officers.
	Special papers.
	Night. Address by Eugene Holman.
April 3 (Wednesday).	Tectonics of the North American Continent by Provinces.
	S.E.P.M. sessions.
	Balloting for officers.
	Dinner-dance.
April 4 (Thursday).	Trends and Developments since 1941.
	Special papers on fields showing exceptional structural development.
	S.E.P.M. sessions.
	Annual business meeting.
	Announcement of Election of officers.

The technical program, as planned, is now practically complete; however, authors of papers on additional or miscellaneous subjects are urged to send their titles and abstracts of 150 or 200 words to reach A.A.P.G. Headquarters, Box 979, Tulsa 1, Oklahoma, by February 15 for inclusion in the printed program. The complete manuscript should be submitted as soon as practical thereafter.

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Stanolind Oil and Gas Company

Meetings: First and third Thursdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

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Vice-President - - - - - Maynard P. White
Gulf Oil Corporation, Box 30

Secretary-Treasurer - - Hamilton M. Johnson
Schlumberger Well Surveying Corp., Box 747

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

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Vice-President - - - - - Roy D. McAninch
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Secretary-Treasurer - - - - - - Carl A. Moore
Carter Oil Company
1300 Apco Tower

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every second Wednesday, at 12:00 noon. Skirvin Hotel.

TULSA GEOLOGICAL SOCIETY
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University of Tulsa

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Shell Oil Company, Inc.

Secretary-Treasurer - - - Glenn R. V. Griffith
U. S. Geological Survey, Box 311

Editor - - - - - - - - Charles J. Deegan
Oil and Gas Journal, Box 1260

Meetings: First and third Mondays, each month, from October to May, inclusive at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Bradford Hotel.

SHAWNEE GEOLOGICAL SOCIETY
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Oklahoma Seismograph Company

Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

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Secretary-Treasurer - - - - Willis G. Meyer
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Executive Committee - - - Henry J. Morgan
Atlantic Refining Company

Meetings: Monthly luncheons by announcement. Special night meetings by announcement.

TEXAS

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Humble Oil and Refining Company

Secretary-Treasurer - - - - Elsie B. Chalupnik
Barnsdall Oil Company, 604 Driscoll Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

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TYLER, TEXAS

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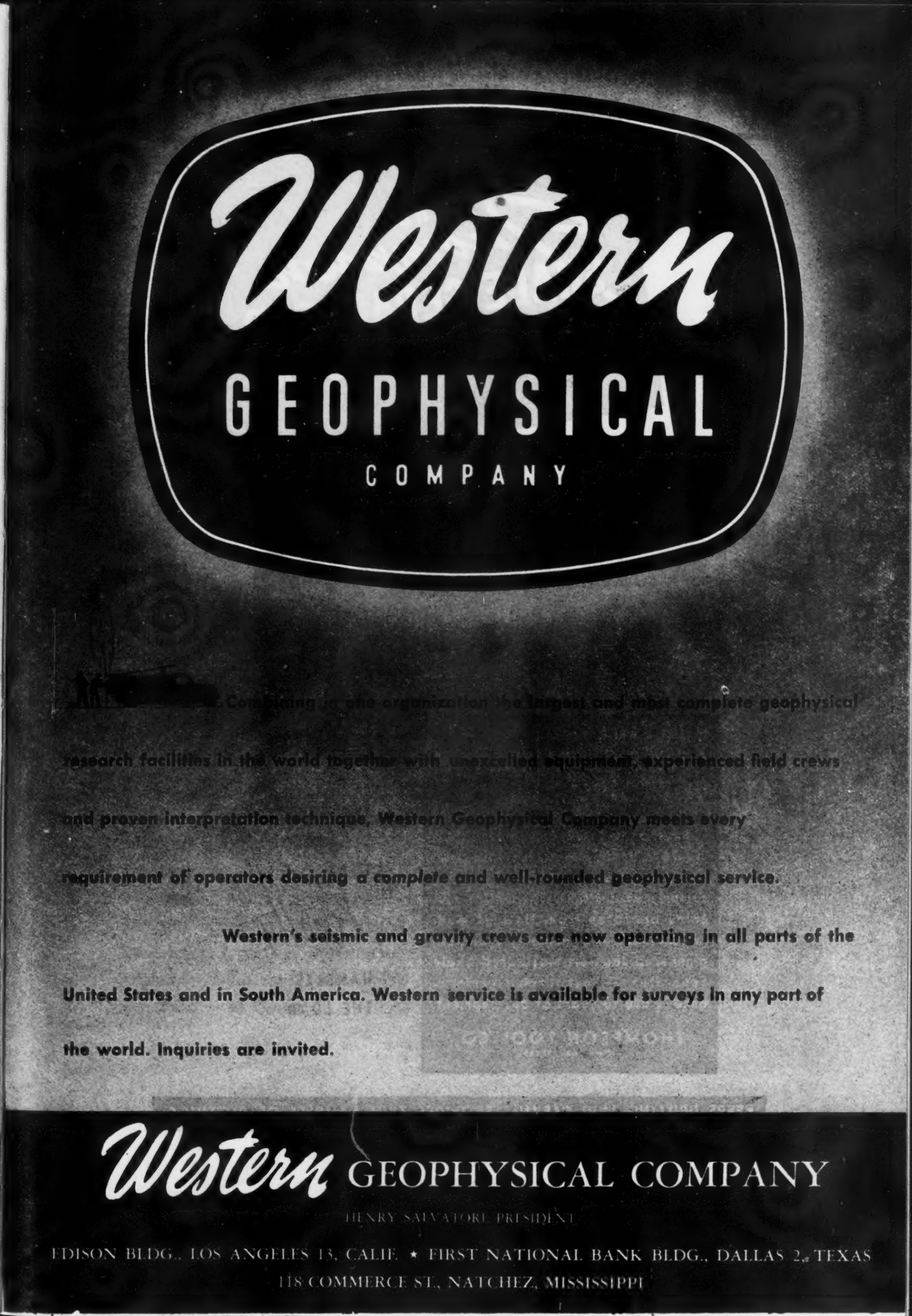
Vice-President - - - - - - - - - F. B. Stein
Tide Water Associated—Seaboard Oil Companies

Secretary-Treasurer - - - - T. H. Shelby, Jr.
Humble Oil and Refining Company

Luncheons: Each week, Monday noon, Blackstone Hotel.

Evening meetings and programs will be announced. Visiting geologists and friends are welcome.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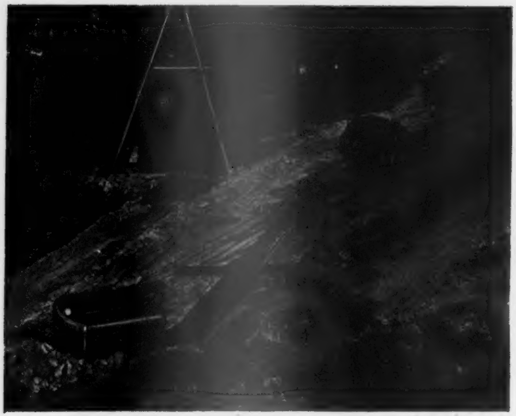

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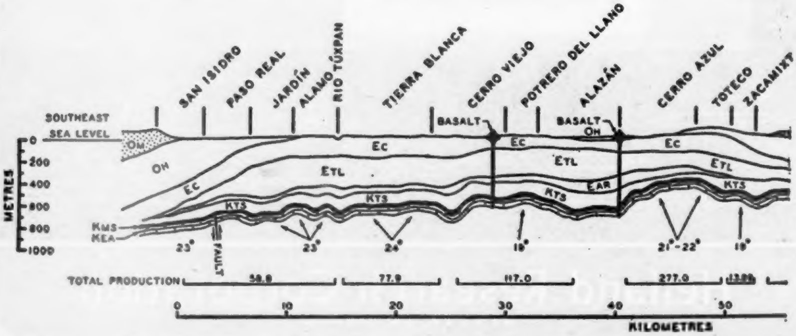
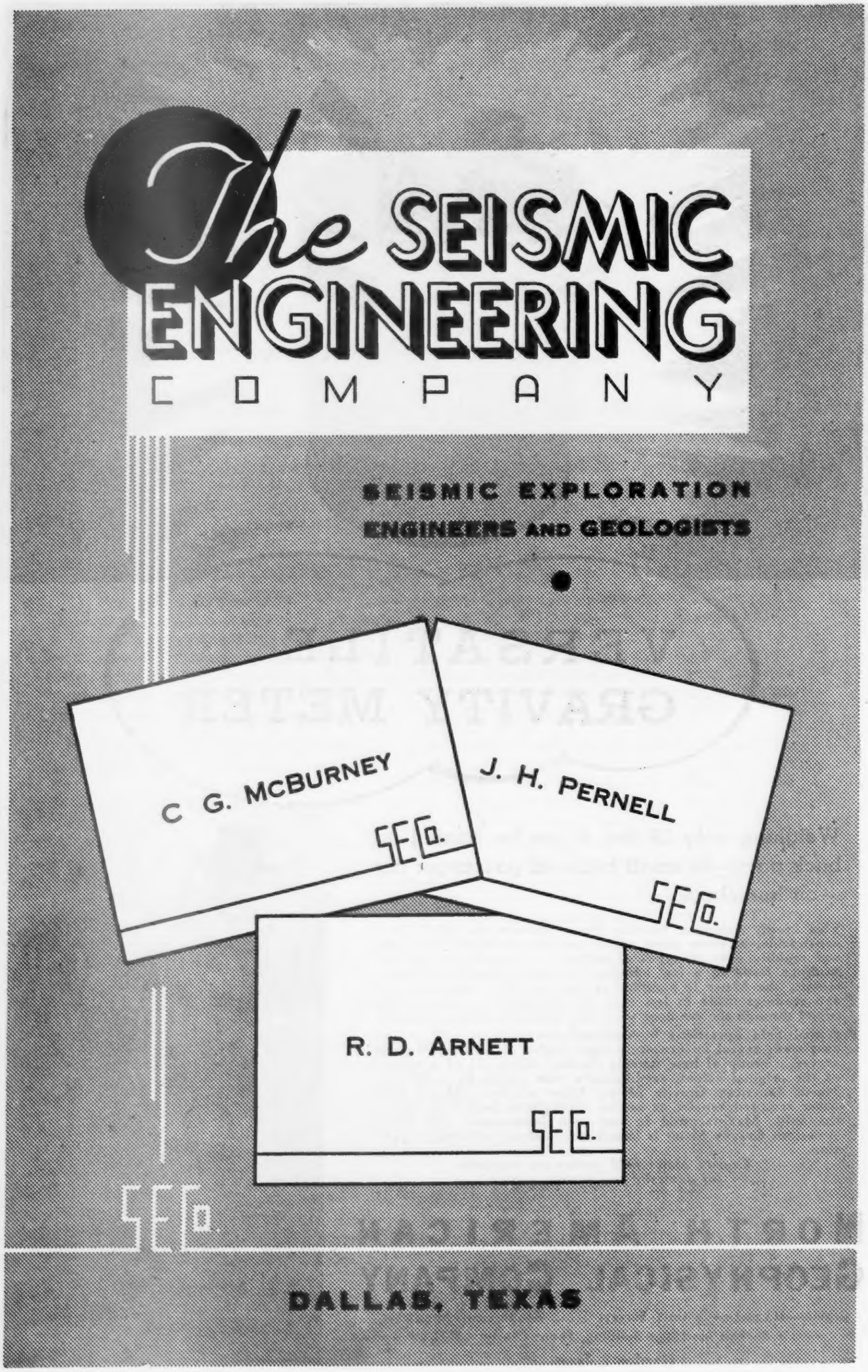
FIG. 20.—Cerro Bernal, volcanic plug. (Reproduction of sketch by Captain G. F. Lyon, 1828; redrawn by F. S. Howell.)





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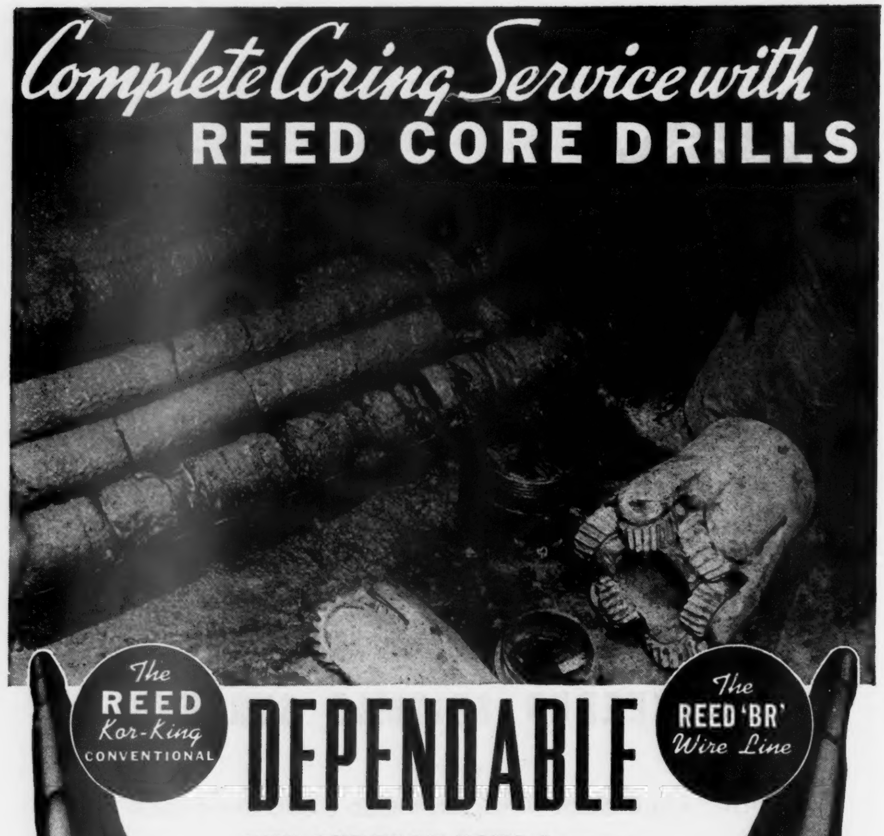
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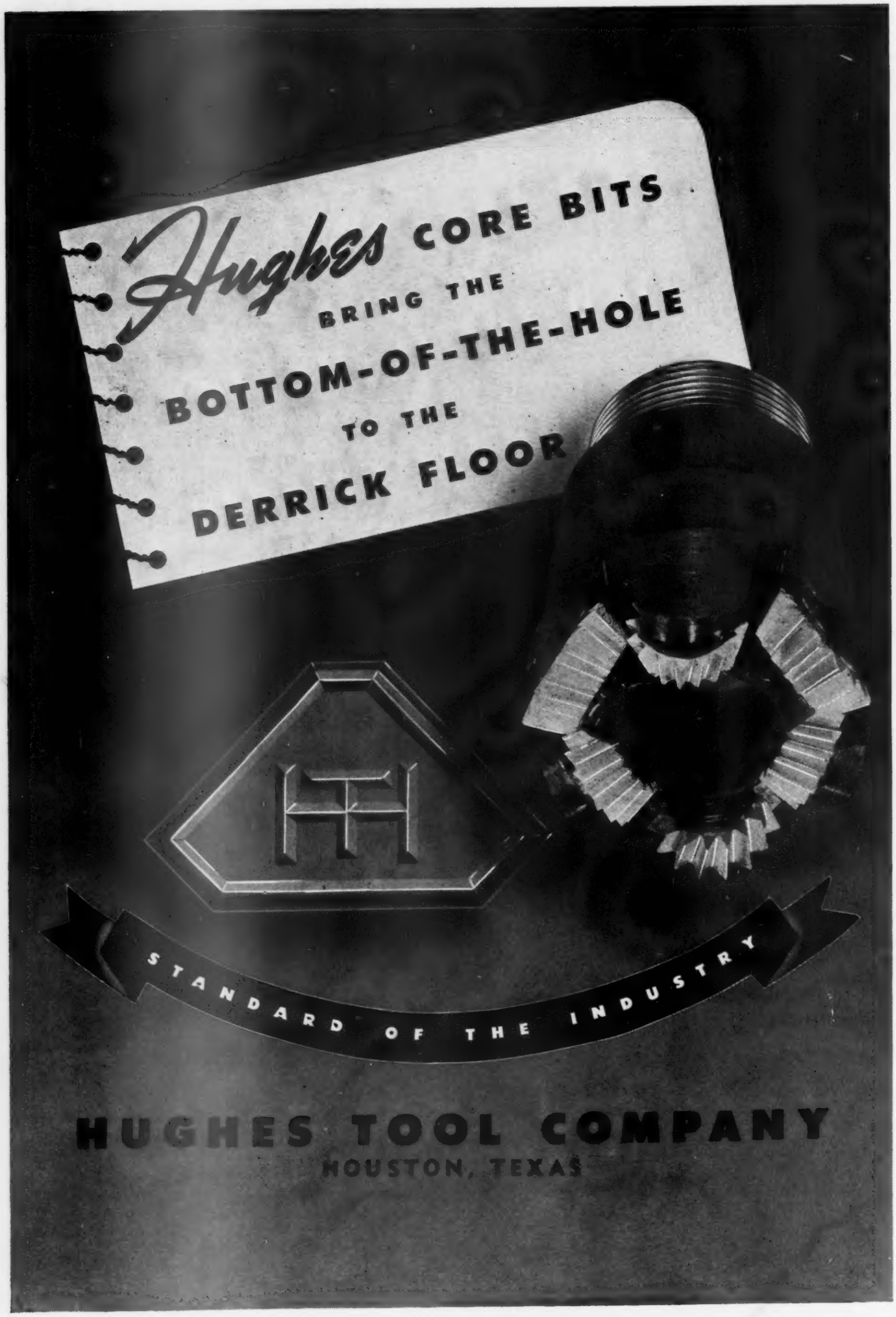
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